THE ECONOMICS OF MINING

THE ECONOMICS OF MINING

(NON-FERROUS METALS)

VALUATION-ORGANIZATION-MANAGEMENT

THEODORE JESSE HOOVER
Dean of the School of Engineering Emeritus
Stanford University

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PREFACE

This book is designed to serve as an introduction to the vast field of mining economy, a subject which has been somewhat neglected in the past but which has assumed in the last few years an increasing importance to all thoughtful mining engineers. No attempt has been made to present a definitive technical treatise but rather to develop in an orderly manner certain theories and methods, in accord with good general practice, resulting from a study of the literature of the profession and tested by personal experience in many parts of the world. An understanding of these principles presupposes no extensive knowledge of the technical side of mining, although some familiarity with technical methods, as well as a modicum of geology and economics, will be helpful in comprehending certain chapters. The general reader seeking an introduction to the subject of mining economy may derive considerable information of value, it is believed, from reading this volume; but it should be said that the work is addressed primarily to young mining engineers who may desire guidance and counsel based on the tested judgments of a senior in their profession.

The subject-matter of this volume has been divided, for convenience in treatment, into three main parts, dealing respectively with the valuation of a mining project, the organization of a mining business, and the management of a mine during its productive life. Examples and descriptions have been drawn primarily from the branch of mining concerned with the production of non-ferrous metals; the particular problems arising from the mining of coal and iron, from the oil and gas industry, and from the mining or quarrying of building materials and other non-metallic minerals have been dealt with at length by other writers.

Many of the chapters herein are devoted to subjects which have grown to form a great body of knowledge, and the brief treatment necessitated here can obviously comprise no more than fundamental concepts, and some notes on their influences on certain problems of the mining engineer. On the other hand, several of the chapters deal with topics on which little has appeared in print and which therefore invite individual research and speculation.

A sincere attempt has been made to give full credit, by means of footnotes and bibliographical references, to the writings of predecessors and contemporaries who are responsible for originating or developing a particular idea, and any failure in this respect should be ascribed to pure inadvertence and an unretentive memory. It is not to be expected that all of the procedures recommended in a volume of general compass and limited space, written in disturbed economic times, will escape the discerning criticism of the fraternity of mining men, and such comments as any of these men may take the trouble to make will be gratefully received by the author.

The present volume is the outgrowth of a course of thirty lectures, with problems and assignments, given to students of mining and economics at Stanford University during the past fourteen years. The course was designed to assist young mining engineers, in the later years of their university training and in the early years of their professional life, to supplement, coalesce, and correlate the instruction they had previously received in the fields of economics, law, business, and accounting, as well as in the technology of mining engineering. The further attempt was made to adduce a broad and farsighted theory by which such knowledge might be focused and applied for the best interests of the mining profession and the public as a whole. It is to be hoped that the publication of a textbook based on these ideals may give an impetus to the more widespread inclusion, in the college curriculum of the mining student, of adequate training in the economics of his field, a subject which enterprising engineers find to be of increasing importance as they advance in their careers. The engineer, one is bound to believe, is destined to achieve a noble eminence in the new world now in the making; but he will not fulfill that destiny unless he surpasses the limitations of the narrow specialist and reveals himself as an understanding student of the social needs of a planned economic civilization.

Thanks are due to Mr. A. Grove Day for assistance in preparing this volume for publication. Acknowledgment is also gratefully made to Mr. A. O. Cautley and Professor E. L. Grant, who read and criticized parts of the manuscript; and to the late Mr. William H. Shockley, who was concerned with the preparation of the syllabus on which this book is based.

T. J. H.

STANFORD UNIVERSITY
March 31, 1933

PREFACE TO THE THIRD EDITION

A considerable adoption of this volume as a textbook in mining schools and inquiries as to its up-to-dateness has impelled this attempt at revision.

Most of the text of the former editions, however, is valid for the postwar world. The period of readjustment is chiefly still ahead; in fact, two generations or more will still be reaping the results of these eventful years. At this writing it does not appear that total peace will be attained quickly, and perhaps it will be the better and more durable for that reason—the engineer does not like sudden changes and high values in the acceleration of his curves.

The attitude of mind in this edition is the same as that in former editions—a strong belief in the endurance of democracy and the profit system and a determination to make them work. Under any other hypothesis the whole of the argument in this book falls to the ground. Only under such alien systems as collectivism, absolutism, and tyranny can metals be produced at a *loss*.

I am under the greatest possible obligation to President Francis A. Thomson of the Montana School of Mines for assistance and inspiration in the revision for the third edition.

T. J. H.

DAVENPORT, CALIFORNIA
January 1, 1947

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Introduction: Mining Economy

How may the metal-mining industry get the most for its money in the long run? That is the broad question this book seeks to answer. Consideration of the question will involve a study of the principles of mine valuation and investment, mine organization and finance, and mine management for efficient production, operation, and distribution—in short, a study of the economics of mining.

Sound mining economy is a body of scientific knowledge that can be applied in the management of mining enterprises to obtain the most profitable employment of capital. Upon its principles the engineer should rely whenever the factor of dollars-and-cents' value enters into any project concerned with the supplying of useful minerals to the world. By a study of costs and revenues involved in such a project he may enable himself to employ with enlightened frugality the resources put into his hands.

The economics of mining engages the mining and metallurgical engineer in his capacity as a business man. Every problem of mining requires for its solution a knowledge not only of technology, but also of economics. In fact, as will be shown, every step from the conception to the culmination of any engineering enterprise calls for some contemplation of value. Mining has been defined as "the art or practice of operating mines *profitably*."[1] Until a mineral deposit may be worked with profit it is merely a prospect. Ore, for example, according to the United States Geological Survey, is "a natural aggregation of one or more minerals from which useful metals may be *profitably* extracted." Hence the mining engineer has come to recognize that the concept of economic value is inextricably fused with the technical development of every mining undertaking.[2]

[1] Dr. Francis A. Thomson's definition is a good one: "The art of making money out of ore."

[2] As long as men are organized in the traditional limitations and opportunities of the profit motive, which is the mainstay of the democratic way of life, this idea of making the mining profession pay will dominate. It is only under an autocratic or communistic type of organization that metals can be produced at a loss; it yet remains to be demonstrated whether these latter forms of government can produce enough metals to erect and maintain a civilization saturated with metals.

There is a human need for metals, and this need is supplied by mining and metallurgical engineering. More and more the progress of human affairs has demanded that economical methods be applied to this quest for and this production of metals, for these reasons:

1. Our civilization has required an increasing annual supply of minerals.
2. The world supply of minerals is decreasing and at the present rate of consumption approaches exhaustion sooner or later.
3. A farseeing economic control must be practiced if the present mineral civilization is to endure.

CONSERVATION OF METALS

Demand.[3]—Civilization has been accurately defined in the following words: "It is the final test of a progressive civilization that a given effort shall produce a larger modicum of average individual comfort, and the pursuit of this ideal has been from first to last the impelling force which drives civilization onward."[4] This "individual comfort," to the mind of the average person of the present day, increases when he surrounds himself with labor-saving inventions such as motor cars, railways, tools and machines, steel-frame buildings, radios, and a thousand other objects largely compounded of metal and requiring the use of metals at many stages in their production. In other words, taking the materialistic view which is almost universal in the world today, one measure of civilization is the amount of metal consumed.

The search for an ideal average comfort and a maximal efficiency is, it may be said, an economic problem; for economy seeks the highest possible ratio of utility to cost.

Our present civilization is based upon an increasing demand for, and utilization of, mineral deposits. The structure of this civilization is like that of the steel skyscraper; its pace is that of the machine of metal, fed by mineral fuel. Every thought or act of our daily lives would be changed if someone, at some previous time, had not somewhere dug something out of the ground. Mining is, with agriculture, one of the two basic industries upon which rests our modern life.

The maintenance of this civilization obviously depends upon a vast supply of useful metals. Those peoples utilizing minerals to the highest degree are those that have builded the great industrial nations today directing the destiny of the world. About ninety million

[3] See p. 193 for further comment on demand.

[4] *Encyclopaedia Britannica,* Eleventh Edition, article "Civilization."

tons of pig iron and six million tons of non-ferrous metals are annually produced; and every large industry is a consumer of this supply. The United States leads all other nations in the production of the base metals such as copper, iron, lead, aluminum, and zinc; it stands second in the production of silver, and third in the production of gold. This country has the greatest variety of mineral products, as well as the greatest production of complex ores, carrying more than one valuable mineral; it has produced about half the world's supply of copper. The English-speaking nations control the world's production of both gold and copper. British and American citizens own seven-eighths of the world's gold mines. The value of the average annual production of useful minerals in the United States lies between five and six billions of dollars.

Disregarding the severe setback of the years 1929–1933, one finds the modern world standing at the highest level of mineral production and consumption that history has known. Around the year 1800, six or seven epoch-making inventions inaugurated an era of mechanization of labor. Manufacture, transportation, communication, and agriculture have been shaped anew by the application of steam and electric power driving metal machines. Great cities have risen to house the growing populations, clothed and fed and carried from place to place by the utilization of minerals. In 1850 the average person in the United States used about half a ton of coal and 55 pounds of iron for the year; in 1910 each person used on the average about five tons of coal and 665 pounds of iron; in 1929, each used about five tons of coal and 788 pounds of iron. In 1930 the estimated annual production of valuable minerals throughout the world reached the staggering total of more than two billion tons. Since 1800 the annual world production of metals has increased more than one hundred times; previous to that date, the store of metals in the world was probably not sufficient to run our modern metallic civilization more than a month. Since the beginning of the twentieth century, more minerals of all kinds have been produced than during the entire history of the world prior to that time.[5]

However, the most interesting fact concerning metal production is not the tremendous yearly totals but the trend revealed by charting the world production since the inception of the Industrial Revolution. Such a curve closely approximates that obtained from plotting the increment on a fixed sum compounded at 5 per cent annually. For more than a hundred years we have accepted as one of the conditions

[5] Thomson, Francis A., lecture at the Montana School of Mines.

of life an acceleration in the production and consumption of mineral resources at a rate not less than 3 per cent, and probably not more than 5 per cent, annually. It is obvious that such an acceleration cannot continue indefinitely, and it is likely that the next few decades will witness a slackening off in the upward sweep of the production curve. Since the beginning of the Industrial Revolution, metals have been produced for an *expanding* market, and demand has increased a certain amount annually. Now it appears that the quota of demand is slowly approaching that of a *replacement* market, and that the amount annually required will be little more than that actually used up or rendered unfit for recovery during the year. Moreover, statisticians tell us that the population of the globe is also approaching a relative stability, so that the demand for metals will not be increased by an accelerating birth rate each year.

The change that will come as an accelerating demand for metals is replaced by a demand with an acceleration approaching zero will be attended by many changes in the conditions under which we live. What these changes will be we can only guess, but under the circumstances it would be unwise to take an alarmist attitude. The slow exhaustion of the world's metal resources may of course cause a proportionate rise in prices of metals in the future. This will in turn encourage the working of deposits of lower grade, the recovery of scrap metal, the invention and use of substitutes, and other measures of economy, and will thus act as a conservational force. Although a rapid flattening of the production curve might work untold hardship on many people associated with the mineral industry, it is probable that the change will be gradual and that a slow adjustment to a fairly stable plane of production will take place in the decades to come.

Supply.[6]—The supply of minerals is limited to certain portions of the crust of the earth and to a maximum workable depth of less than 10,000 feet. Except for a few pounds of meteoric iron, the sun and planets and stars can yield us none. For hundreds of thousands of years, quantities of minerals have been carried into the oceans, which cover nearly three-fourths of the earth's surface. We may possibly find a way by which some of these will be recovered. Of the land surface of the globe, large areas—such as parts of the polar regions and the tropics, as well as rural and urban districts that, for obvious reasons, will probably never be dug up—cannot yield any great supply.

[6] See p. 193 for further comment on supply.

The metals and other minerals in the remaining areas are fixed in quantity; they do not increase or grow. A mine differs from most other industrial enterprises in that it is a diminishing or shrinking asset, a "one-crop" venture. Every ton of metal taken from the ground constitutes a bank-draft upon posterity. Future operation will demand the mining of increasingly lower grade ores on an increasingly large scale, and even these deposits cannot last forever. The old lucky days of the fabulous "grass-roots" deposit, discovered in surface croppings, easy of exploitation, and financing its own development as it went along, are past. The last quarter century has seen the rapid exhaustion of most of these high-grade properties; and today the highest possible technical skill, financial planning, and economic management are needed in order to offset the steady rise in cost of production that will ultimately result from exploiting deposits of lower and lower grade.

Already we have drawn heavily upon our stocks of useful metals. Research and improvement in metallurgy and geological science may defer the distant day of reckoning by the discovery of new methods of extraction that will make it economically profitable to handle grades of ore with lower and lower metallic content. The introduction of the flotation process, for instance, permitted the economical production of copper from ore containing as little as eight-tenths of 1 per cent of metal, whereas previously, ores with a minimum content of 2 per cent were demanded.[7] Alloys and other alternatives may be discovered that can be substituted for the rarer metals and thus serve to eke out the present stocks. A cheap method of extracting the abundant metal aluminum may stave off the rapid consumption of other base metals. Titanium, which is plentiful, may be used to replace lead and zinc in the making of pigments. Geophysical methods may uncover deposits unguessed by old-time prospectors. But research, although it can create substitutes and otherwise eke out the supply a bit farther, cannot create or replace an exhausted supply.

Reno H. Sales, in an address to the Mining Congress in Denver, September 1946, gave the American people an eloquent and solemn warning which cannot be abbreviated or omitted in a text for the guidance of future generations of mining engineers.

In general, exploration for hidden deposits by drilling, shaft sinking, or geophysical survey, is too costly for the normal type of prospector. His pick

[7] See Hoover, Theodore J., *Concentrating Ores by Flotation*, 3d ed., pp. 187–200.

and pan will prove to be of little service. But a good many things can be done to encourage prospecting. Among these are:

1. Establish laws or regulations which will permit mining locations to be made and held for a period of time upon lands having no outcroppings of veins or solid rock surfaces.

2. Continue efforts to perfect geophysical instruments and other types of prospecting equipment. In anticipation of improvements in geophysical instruments our mining laws should make it possible for a prospector to take out a limited-time prospecting permit covering a considerable acreage. Within such time limit, claim locations could be made, if desired, covering selected ground within the permit for drilling or testing by other means. . . . .

3. Develop the art and use of aerial photography, particularly color photography, to expedite the mapping of geological formations, faults, and evidences of mineralization.

4. As a practical aid in the search for hidden deposits, it is recommended that the United States Geological Survey not only intensify its field work, but give serious attention to the subject of pediments in anticipation of favorable developments in geophysical instruments and prospecting methods. An outline of pediment areas on geological maps covering regions or limited areas having mineral possibilities might prove very helpful.

Conclusion.—It is my opinion that the "must" course of action for our nation is one that will insure continuance of operations in our important mines and mining districts until all ore obtainable within a reasonable metal price limit has been exhausted. The marginal, possible, and prospective ores of these districts far transcend in importance at the moment the so-called "vast unscratched resources" awaiting discovery. We should not sacrifice our best prospects on the theory of finding ore bodies which may not exist. The lesson of 40 years of prospecting has taught us just that. At the same time everything possible should be done to aid and encourage the prospector and the small miner, because it is to them we must look for the original discoveries from which reserves are ultimately developed. . . . .

Finally, let no user of copper, lead, or zinc, whether he be manufacturer, or ultimate consumer, be lulled into a state of complacency by those who advise that if and when our copper, lead, and zinc reserves are exhausted, we will import our needs from foreign countries. What foreign country . . . . and at what price? Most countries have been prospected except in remote or inaccessible regions. No one at this moment has good reason to expect that new important deposits in foreign lands will be found more easily than in our own. But assuming a build-up of foreign reserves, and that the time may come in the not distant future when our status will be that of a truly "have not" nation, import prices may be such as to make our present day metal prices seem ridiculously low.

This nation must preserve its mining industry as long as possible and maintain it at high standards of efficiency, which means the preservation also of our technical skill. We must protect also the interest and enthusiasm of the individual for prospecting, mining, and "striking it rich," built up since the day of gold discovery in California, and not allow it to die with this generation or the next. If we fail, those who will suffer most eventually are the great manufacturing industries using copper, lead, and zinc; and along with

them that every day American citizen known as the "ultimate consumer," who finds one or more of these metals in nearly every article of commerce designed to raise his standard of living.[8]

Control.—The waste of metals is of two kinds, waste in production and waste in consumption.

The waste in mining some minerals is large, notably in the case of fuels (coal, about 50 per cent, and petroleum, perhaps as much as 80 per cent); the mining loss for non-ferrous metals is much less. The waste in metallurgical recovery from these ores, after they have been brought to the surface, is very small; every device of the metallurgist is used to recover the last possible ounce of metal from the ore.

The waste in metal consumption—which does not include unavoidable destruction such as the utilization of large quantities of lead and zinc in chemicals and pigments and non-corrosive coverings, but rather waste through sheer extravagance and dissipation—is estimated to amount to about one-tenth of one per cent of annual production. This does not look to be an alarming fraction until one recognizes that it represents a hundred thousand tons of metal a year, which is probably more than the human race had in its possession up to the beginning of the Christian era. The junk-yards of the nation are not large enough to hold the reclaimable scrap metal, second-hand automobiles, and the like; although the scrap-metal industry is rapidly growing in importance.[9] Rare and highly valuable metals such as radium are used in ignorance that cheaper ones will serve, and thus we see our precious stock of radium being used to make luminous watch-dials. The industrial nations of the world have scrambled to stake out their claims before the others located; now, like prospectors who have struck it rich, they pour their bonanzas through their fingers, without a thought that the vein will some day "peter out." The famine for some metals is already within sight—for the precious metals gold and platinum, and for tin.

The phenomenal growth and prosperity of the United States in the past owes more to the intensive exploitation of its immense resources of iron, coal, oil, gold, copper, and other mineral products that are the raw materials of industry than to any other single factor. But we are slow to learn the lesson of conservation. Other countries,

[8] Sales, Reno H., *Ore Reserves and Future Exploration* (reprinted from *Mining Congress Journal,* October 1946).

[9] See Tryon, F. G., and Eckel, E. C., *Mineral Economics,* chap. 8, "The Rise of Scrap Metals," by H. Foster Bain.

in order to protect their mineral heritage from exploitation by aliens, to their national, military, and commercial detriment, have passed rigid measures. Unless the present generation in this country perceives that the resources of our republic must be handed on unplundered to our posterity, our country stands in grave danger of having to beg from its rivals, paying dearly for the wealth we shall have tossed away; or of facing the alternative of snatching from feebler hands resources which they have retained because of their lack of industrial initiative. If we believe that the civilization in which we live is a good one, that it represents ten thousand years of man's physical, mental, and spiritual development, that our present culture is worth saving and maintaining, as well as improving—if we believe these things, then we are forced to conclude that our duty as engineers demands a wise and conscientious control of our mineral wealth.

The duty of the engineer is plain, if he is to carry on his function most intelligently for the advancement of civilization. He must, through an application of the principles of sound planning for the future, endeavor to check in every way the prodigality of our times. The economic control of mineral resources is dictated by no mean parsimony or soulless materialism. Voluntary reform in consumption habits for the elimination of waste must take place, unless we desire to suffer the consequences of compulsion.

THE IMPACT OF WORLD WARS ON MINING ECONOMY

Engineers of my acquaintance have suggested that the matters discussed on these introductory pages do not lie within the province of the mining engineer. I disagree wholly with this criticism, for one reason among others, that the mining engineer should know better than anyone else what the world reserves of minerals are; he should also be—and he generally is—informed as to the intricacies of demand.

Article 4 of the Atlantic Charter postulates the free and equal access by all peoples to the crude resources of the world. Our whole foreign policy is based on the fond belief that the mineral resources of the earth are larger than they actually are, and that they are adequate to implement the Atlantic Charter and the articles of the San Francisco Charter. Certain inevitable corollaries follow from these postulates.

The last thirteen years present some new aspects to the mineral picture:

1. For the first time in history an avid increase in the need and demand for metals has not been met by an increased production; this situation is due to price fixing, strikes, and decreasing reserves. The law of supply and demand can be obstructed.

2. We (by "we" I mean those peoples who are the beneficiaries of what we call "Western civilization") emerge from this war with a staggering obsolescence of the whole metallic structure, and we fondly hope for a "rapid recovery"! This repair of obsolesence in the area of Western civilization alone would place a terrific strain on our reserves.

3. Let us call the annual prewar production two billion tons of minerals, with an acceleration of 5 per cent per annum. The term "Western civilization" applied more or less to 650,000,000 people.[10] This amounts to, as near as possible, three tons per person. Now China, India, Russia, and others are demanding two cars in every garage, refrigerators, radios, and all the comforts and gadgets of the Western world. There are 1,500,000,000 of these new demanders. If these demands are ever to be met, an annual production of 6,500,000,000 tons of minerals, with an acceleration of 5 per cent per annum, is needed. This figure is utterly fantastic; there is no such mineral supply this side of the Milky Way.

4. If Russia and China *et al.* are to be supplied with even a meager quarter of this tremendous figure of three tons per person, it means one of three prospects: (1) either new and wholly unknown (at the present time) deposits will have to be found; or else (2) we will have to make an astounding development in the use of substitutes, plastics, wood, etc.; or (3) "we" will have to get along with less. I do not see the average American reducing his three tons in order to give the members of less fortunate nations even one ton per annum. On the contrary, the average Western man's present demand is for more of these gadgets.

The acceleration of the curve of metal production (5 per cent per annum) is, I believe, on the point of changing downward. This present rate means that the production (and consumption) doubles every twenty years, or five times per century. Even without the demand for gadgets from those hitherto unsupplied, this rate would mean an annual production in the year 2040 of 10,000,000,000 tons—another fantasy.

[10] See *World Almanac and Book of Facts for 1946.*

THE PROCESS OF ENGINEERING[11]

Further to appreciate the duties of the engineer, one should designate more rigidly the status of his profession among the activities of mankind.

Engineer and scientist.—It is not easy to draw a line of demarcation between the activities of the engineer and those of the scientist. Those men who contribute most to civilization share the attributes of both types, and workers in either field of endeavor, in order to succeed, must have the same habit of mind. The primary activity of both classes is research; and it is sometimes merely accidental that the fruits of scientific research have a "practical" value. The scientist prosecutes research for the purpose of gaining knowledge of nature, while the engineer does so for the purpose of applying scientific knowledge (especially that developed in the physical sciences) to a useful end. Unlike the "pure" scientist, the engineer is called upon to use, in addition to units such as mass, volume, force, and time, certain units representing value (i.e., economic). He must also allow for other considerations—social, political, and cultural—in which the human factor is predominant. But the domains of pure science and applied science are complementary; either would be useless to humanity without the contributions of the other.

Remembering that most workers in scientific fields are concerned with both pure and applied science, it may be well to mention extreme examples of both classes. Charles Darwin may be cited as a pure scientist in the fields of geology, paleontology, and biology; no one asserts that his discoveries were of no practical use, but merely that their useful applications did not interest him or act as a motive for his researches. Thomas A. Edison, although his name comes to mind as a worker whose efforts were chiefly directed to the discovery of knowledge of immediate utility, was a self-taught scientist of no mean capacity, and proves the truth that one must know before one can do. Some men, like Joseph Louis Gay-Lussac, devote part of their lives to disclosing natural laws, and part to applying scientific discoveries to industry; such men, of high mental attainment, may be eminent in both fields of endeavor.

The functions of engineering.—Engineering has been defined by the Federated American Engineering Societies as "the science of

[11] For a more extensive discussion of this subject see *The Engineering Profession*, by Theodore J. Hoover and John Charles Lounsbury Fish, Stanford University Press, 1940.

controlling the forces and utilizing the materials of nature for the benefit of man, and the art of organizing and directing human activities in connection therewith." This definition seems much too broad; but it is difficult to formulate one that will clearly separate the various phases of man's endeavor. Another definition is: "Engineering is that profession the members of which design and operate methods by which money, men, and materials are used to convert natural resources into forms useful to man."[12] This definition is much too broad; its wording would include agriculture, dentistry, and many other fields. Moreover, many of the engineer's functions are only indirectly beneficial, serving to level the ground or prepare the way for construction; while the ingenuity of the military engineer cannot be said to benefit those against whom it is directed.

When this definition is contrasted with the definition of "civilization" given on page 2, the similarities and inclusions of the two are startling. Each was constructed by groups of men with widely divergent training, experience, and interests; yet their boundaries are, in part, coterminous. The activities of the engineer produce the increasing modicum of average individual comfort upon which the existence of civilization depends.

Engineering projects of all kinds, when analyzed, may be reduced[13] to the following elemental steps:

1. The conception of a human need
2. Research, analysis, and planning a project for the supplying of that need
3. Valuation of the project
4. Organization and promotion of the project
5. Design of mechanism to carry out the project
6. Construction of the mechanism
7. Operation of the mechanism
8. Maintenance and inspection of the mechanism
9. Sale and distribution of the product

In this manner the human need is supplied.

Such an analysis shows plainly the large economic component in all engineering projects. It also shows that a large group of people —some to furnish capital, others to act as promoters and organizers and managers, and still others to serve as engineers and professional consultants—must be enlisted if the need is to be met.

[12] *Journal of Engineering Education*, September 1946, p. 67.

[13] See Fish, J. C. L., *Engineering Economics*, pp. 3–4.

For convenience, the above nine steps may be re-grouped into successive related functional pairs, thus:

1. Research and invention 2. Valuation and finance 3. Organization and promotion 4. Design and construction 5. Operation and production 6. Maintenance and safety 7. Testing and inspection 8. Sales and distribution	Management

Management or control has to do with the logical co-ordination of all eight of these pairs, and can be applied to any particular pair. Management is the planned synthesis of all factors that gives the project a unified aim and intelligent direction.

The placing of "valuation" in the second of these successive steps may be challenged on the ground that a correct valuation cannot be made before "design" and all the later operations have been carried out. This placement may, however, be justified by pointing out that "valuation" is a process of estimating future worth, and should be distinguished from "appraisal," an estimate of actual worth for the purposes of taxation or insurance. Valuation is the answer to the question "Will it pay?" which invariably arises at once in any discussion of a new project to satisfy a human need. It is "valuation" in this sense that will be elucidated in these chapters, rather than *ex post facto* "appraisal" for income tax or other purposes. The fact that no exact valuation of a project can be made at this early stage does not release the engineer from the task of preliminary estimation of values and costs, an estimation as complete as he can make it. Indeed, the chief usefulness of the engineer in our social organization is that he is trained to make, and that he cheerfully undertakes, these tentative valuations from scattered and imperfect data; he relies on his own past experience and the accumulated experience of others to give him a reasonable basis for his prophecy of the future.

The engineer, in carrying out this tentative valuation as in carrying out his other activities of design, research, organization, etc., has recourse to a method that, in the process of time, has come to be called the "engineering method" of approach. This is a method of research, defining the word as diligent inquiry, examination, or study; laborious or continued search after facts and principles. The engineer in this study may confine himself largely to measurements

and calculations, but often he will utilize the apparatus of the laboratory as well. In the one case it might be said to be statistical research, and in the other, laboratory research. There is no definite line between the two; they merge and coalesce. Of research and its bearing on engineering more will be said in chapter 23.

THE ENGINEERING METHOD FOR SOLVING A PROBLEM OR PLANNING A PROJECT[14]

The engineering method used to solve a problem or to plan a project is divided, according to the conception now to be outlined, into three steps: *analysis, measurement,* and *integration or synthesis.* The author is indebted to Professor J. C. L. Fish, head of the Department of Civil Engineering, Stanford University, who prepared the original memorandum upon which this section is founded. Some liberties have been taken with his original statement.

Analysis.—The engineer makes a list of all the factors of the problem known to him, indicating the interrelations of all the factors with each other. Diligent search is made in all the environs of the project for additional factors, and he endeavors to see that none have been overlooked.

Measurement.—Each factor is carefully measured in its appropriate units, and, in so far as is possible, all interrelations of factors are given quantitative values. For the detection, measurement, and calculation of material factors of a problem the engineer has a variety of instruments—the transit, level, ammeter, wattmeter, microscope, chemical balance, slide rule, comptometer, and many others. Skill in the use of these instruments, as we shall see, is only a part of the engineer's professional equipment.

It will soon be found possible, as a result of the measurements, to arrange the factors of the problem into categories, thus:

1. Exact quantitative factors, which can be measured and given exact values.

2. Approximate quantitative factors, which can be partially measured and given approximate values.

3. Qualitative factors, the values of which must be sensed through the exercise of reason and good judgment. The word "sense" in this connection is used to mean the perception, by a capable observer, of degrees of difference in the possession of a

[14] *The Engineering Profession,* by Hoover and Fish.

quality.[15] Examples of sensed differences in qualitative factors later given in this book are: the forecasting of future prices; the estimation of the life of a mine; the determination of the degree of risk in a mining enterprise. This sensing is based on the accumulated knowledge and experience of the past. Some engineers consider these factors listed as qualitative to be qualitative in the sense that their valuation must necessarily be stated in figures, though inexactly. Herbert Hoover, in *Principles of Mining,* says: "It is impossible to assign to any mineral property an absolute definite value, but only a most probable value."

Integration.—When the engineer has broken the problem down into its component factors, and when he has measured or sensed the magnitude and power of each factor and the forces of interaction between factors, he can then combine the factors by computation and thus secure the answer to his problem or formulate the scheme for his project. This process may be termed "integration," or the formation of a whole from constituent parts.

Engineering problems and projects may be classified according to whether their elements are quantitative, qualitative, or mixed.

1. Those based on quantitative factors that can be accurately measured and combined to give an exact answer. These cases are simple, and do not occur frequently in engineering practice.

2. Those based on quantitative factors that can be only approximately or partially measured which will, in combination, yield only an approximate answer. The procedure in this second case is as follows:

a) Combine the determined exact and approximate factors into an approximate answer.
b) Estimate the degree of uncertainty in the approximate answer.
c) Attach to the approximate answer a statement of the degree of uncertainty determined.

It is common knowledge derived from experience that the answer to a quantitative problem, in spite of correct computation, will be in error (1) if a relevant factor is overlooked, (2) if an irrelevant or incorrect factor is included, or (3) if an interrelation is confused. It is also common knowledge that, although such an error may cause disaster, the error, as well as the cause of the error, is usually readily detected if sought with care. Under the spur of this knowledge, men charged with solving quantitative prob-

[15] See Kelley, T. L., *Scientific Method,* p. 89.

lems have devised and tested ways of reducing to a minimum the risk of making such errors. The best way yet found, the way most common in current use, is to exhibit the factors graphically and in such array as to make vividly clear the interrelations. Common expressions of this systematic process are the established rule, the algebraic formula, the scaled graph, charts, tables, etc.

3. Those based on mixed factors, involving exact quantitative, approximate quantitative, and qualitative factors. These can yield only an approximate answer, and the procedure is as follows:

a) Combine the determined exact and approximate quantitative factors into an approximate result.
b) Estimate the degree of uncertainty in the approximate result.
c) Sense the effect of each of the qualitative factors and sense the effect of their combination.
d) Sense the answer from the combination of (*a*), (*b*), and (*c*).

In the case of the qualitative or mixed problem, as in that of the quantitative, it is common knowledge that error results from omission of factors and from confusion of interrelation. But there the parallel ends. In the first place, error in the answer to a qualitative problem is not readily detected unless egregious, and even if the error is detected, the cause of the error, being difficult to discover, is not always sought and more seldom found. In the second place, a means of expressing clearly the vague interrelations between the vague factors of a qualitative problem are difficult to devise. Neither rule nor algebraic formula can be forced to serve. Because of this difficulty of devising clear means of expressing interrelations and because such blunders as occur are likely to be shrouded in the same fog that causes them, there has not been sufficient pressure to make current any systematic procedure for the solution of a qualitative problem.

Most of the university training of the student is concerned with the solution of quantitative problems; but when he takes his place in the world of practice he is almost always faced with mixed problems. He should therefore attempt early in his studies to avoid the slavish following of formulas, to trace the formulas in his textbooks to their logical sources, and to judge whether or not their terms are applicable to the factors of his particular problem.

The process of evaluating the worth of a mining property, as delineated in the first section of this book, constitutes an excellent example of the combination of mixed factors. In this case more or

less accurate quantitative factors obtained from measurement and sampling must be weighted with a number of qualitative factors in order most intelligently to value the mine.

APPLICATION OF THE ENGINEERING METHOD

A great part of the mining engineer's problems are approximately quantitative, or mixed. The engineering student has continuous drill in quantitative problems, and at graduation is likely to have acquired, as a fixed habit for solving a quantitative problem, the following routine:

He deliberately sets out to uncover every pertinent factor, and carefully determines their interrelations.

He sets up the factors in some graphical array with the fourfold object of: (*a*) making conspicuous the absence of a pertinent factor; (*b*) guarding against forgetting a factor already recognized; (*c*) making conspicuous a confused interrelation; and (*d*) guarding against confusing an interrelation that has been once clearly recognized.

He distinguishes between exact and apparently approximate factors, examines each apparently approximate factor with the intention of discovering a practicable way of rendering it exact, and, if he finds such a way, does so.

He estimates the degree of uncertainty in each remaining approximate factor and the effect of that uncertainty on the answer, expressing the uncertainty in maxima and minima.

He finds the combined effect of the factors by calculation; and, if one or more of the factors are approximate, he estimates the corresponding variation in the result.

Now he has arrived at an answer; but the dread of error prevents him from resting content. He sets about testing the answer, thus:

He reviews afresh all the steps—of logic, of judgment, and of calculation. As another check he analyzes the problem a second time, but along lines that diverge as far as possible from the lines of the first analysis, and completes a second solution. And yet he is not content until he obtains independently a sensed answer based on all the pertinent portions of his past experience and finds that the answers agree within reasonable limits. Even now he is not content because behind that impenetrable curtain that walls him off from the future there may be something over which he has no control and

no previous experience which will warn him of its presence. Consider the case of the 4 per cent gold bond (pages 185–86 and 317).

When the engineer is charged with problems involving a greater and greater proportion of qualitative factors, habit leads him to make persistent effort to place them in such graphical array as to indicate as clearly as possible the interrelations. And in evaluating the apparently qualitative factors, habit leads him to scrutinize each with a view to the practicability of making it approximately quantitative; if practicable, he makes it so. The remaining qualitative factors he classifies according to whether they are based on fact, authority, opinion, or surmise.

Through the use of such a method as the foregoing, the engineer, although he may find it impossible to deal at all points with a qualitative or mixed problem with the same precision as with a quantitative problem, nevertheless finds that this general systematic procedure will give as the solution of any problem or project the closest approximation that human ingenuity can devise.

The method described does not in all strictness deserve to be called the "engineering method," for it is too general in its logical principles and too wide in its applications to be branded as the special instrument of any particular art or science. The so-called engineering method is simply one form of the scientific method as it is used by engineers. It is a method of solving problems in which the solver is actuated by an almost fanatically rigid adherence to a conscious effort to take complete cognizance of all the available facts.

The past is strewn with glaring mistakes in estimating engineering projects as a result of not applying the engineering method with care and discernment. Of many of its past performances in this regard the profession has no cause to be proud; far too many underestimates have been made on future capital requirements and probable costs of operation, as well as overestimates of probable revenues; nor have the sequelae of overproduction been given due forethought. In every case the mistake lay, not in the method itself, but in its application. And the errors do not so much occur in determining strength of structures or the capacity of machines, as in a lack of understanding of economic factors. The most glaring of these errors occur in the fields of irrigation, water works, municipal services, and mining. The engineer has yet much to learn concerning financial and social planning, but he would seem to be in a position at the present time, by education and experience, to become probably the most powerful unit for human betterment.

The engineering method is of especial value in controversies. Whenever there is any clash of interests, the attempts at settlement may take three forms:

1. *Conflict.* The "knock-down-and-drag-out" fight, in which one side is victor by reason of superior strength, and afterward consolidates and maintains its gains. In this method the public is the chief sufferer, although it is an innocent bystander.

2. *Compromise.* This is the fashionable method. It is generally ineffective and is often resorted to while the warring interests arm for the future. Arbitration awards in labor disputes are a conspicuous example of the weakness of this class of treatment; they seldom settle anything. Here again the public is the chief sufferer.

3. *Integration.* This is the so-called "engineering method." During this process all the factors of every difference between the conflicting parties are dragged unceremoniously into the open for inspection, analysis, measurement, comment, and ultimate combination to obtain the solution. Since integration involves pulling all the niggers out of all the woodpiles, the contestants often show considerable opposition to the employment of this method. Complete analysis of the sort required for the integration process often leads to revaluations by both sides, because, after all the hidden factors are brought to light and subjected to close inspection and candid criticism by antagonists and mediators, these factors do not always seem so valuable as before, even in the eyes of their proponents.

It is of interest to note that when the integration method is employed, the needs of the general public, which do not necessarily coincide with those of either party and, indeed, in many cases are conspicuously at variance with them, may easily be segregated and set forth.

THE FIELD OF MINING ECONOMY

The broad field wherein the principles of mining economy may be usefully applied has been divided, for the purposes of this book, into three sections. These sections are arbitrary: the scope of each has been limited for convenience in study; and each may roughly be considered the basis of one quarter's work in a course in the economics of mining. The sections, with the topics to be included, may be briefly indicated as follows:

1. *Mine valuation.* The elements of mine examination; sampling and measurement; economic geology; tonnage calculations; analysis of costs and mining and metallurgical losses; prices of

metals; smelter contracts; estimation of profit; and valuation reports.

2. *Mine organization.* Forms of business organization; the promotion and sale of mines and shares; principles of investment; the stock market; the valuation of mining shares; frauds and visionary schemes; and mining law and taxation.

3. *Mine management.* Staff personnel, training, and discipline; scientific management methods; efficiency and research; industrial relations and labor problems; sanitation and accidents; and the profession of mining and metallurgical engineering in its business aspects.

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PART ONE
MINE VALUATION

Chapter 2

Initial Phases of Valuation

The factors involved in the valuation of a mining project are so complex and various that ideal exactitude is impossible. The valuation of a mine is the process of estimating future profits, and here as elsewhere, prophecy is dangerous. However, if the engineering method is applied with care and intelligence, an approximation may be made that will place the value of the mine within certain rather wide, but definite, maximum and minimum limits.

The main purpose of the following chapters is to discuss the various factors of valuation and make them familiar; they lose something of their terrifying aspects upon acquaintance, and their very number is less disconcerting to the inexperienced engineer upon closer scrutiny. Many factors can at once be eliminated as insignificant or can be assigned definite weights. The unknown factors that cannot be eliminated or defined constitute the element of risk that enters into any business undertaking—although the risk in mining ventures, be it said here, is in the aggregate a very great one.

A preliminary view of the process of valuation should include: first, a brief sketch of the theory of valuation; second, a description of the problems confronting the engineer at the time the need for valuation arises; and, third, an outline of the commonest factors that must be integrated to produce a logical conclusion as to the value of the property.

THE THEORY OF VALUATION

The ore in the mine must ultimately pay for the following:

1. Purchase price
2. Development of the deposit
3. Plant and equipment
4. Costs of operation and treatment
5. Interest on the money invested
6. Profit to the organizers and investors

The engineer's problem, briefly, is to decide whether the sale of the ore that he estimates the mine can produce will, at the time this ore

is sold, pay for the expense of mining it and likewise yield a suitable return for the capital laid out. Since no two mines are exactly alike and since the circumstances of each sale may differ widely, this problem varies for each particular mine under valuation.

Purchase price.—The first stages of a mine's development are usually in the hands of the original locator or a few associates; but sooner or later, as the business expands, these persons must sell the property to others with greater financial strength, or take the latter into partnership. Any program for continued operation must include in the valuation the amount laid out for the purchase of the property. This purchase price is therefore one of the deductions from the value of the ore in place that must be made in determining the value of the mine.

Development. — A deposit is opened up by tunnels and shafts, drives, raises, and winzes until it is pierced by openings from which the ore can be cheaply and safely extracted. This development work is expensive, as is the exploration that must precede it, and should be kept well in advance of actual ore-extraction. The estimated cost of such development is also one of the deductions that must be made in valuation.

Plant and equipment.—Most ores require a series of complicated processes for the extraction of the relatively small amount of metal from the ore mined. These processes demand an adequate plant and costly machinery for extracting, handling, and treating the ore. The capacity of the plant and equipment must be properly adjusted to the size of the mine and the contemplated output; and the estimated cost of this necessary outlay is another item of deduction in determining the value.

Operation.—Total costs of operation, including materials, labor, and power needed in maintaining the mine and plant, as well as all administrative charges and expenses, must be borne by the sale value of the metal or mineral produced, and these are a deduction in determining the value of the mine.

Interest on investment.—Several years may elapse between the time the mine is purchased and the day the first product is marketed. All the money that has been paid out in purchase, development, and equipment will, if borrowed, draw interest; if it is not borrowed outright but raised by issuing shares or otherwise, it should show a periodic return at a high rate, because the business of mining is one

of uncommon risk. Since any money invested in the mine could otherwise be employed to earn an income, the accumulated interest for this period is therefore a legitimate item of expense in the valuation of the enterprise.

Profits.—Those investing in mining ventures quite properly expect to receive back in time all the money expended for purchase, development, equipment, operation, and interest. They also expect profits, and these in no small degree. No sensible person would invest in a mining business and be content to receive a profit of 5 or 10 per cent yearly. The dream of most mining investors is not often reduced to cold figures, but it would not be too much to state that 100 per cent per annum is not an exorbitant estimate of their expected profits. A high expected rate of return can be thoroughly justified by considering the risks involved in mining and the wreckage of futile and unsuccessful ventures in the past.

The idea that the investor expects to receive back all his capital, plus interest, plus a large profit, is implied by the processes represented by such terms as "amortization," "depreciation," and "depletion." The meanings of these terms will be discussed in later chapters.

PRELIMINARIES TO VALUATION

The valuation of mines is a part of the work of the mining engineer that calls not only for scientific and technological training but for business acumen and experience as well. Not long ago, when engineering began to evolve as a profession, engineers were supposed to have no commercial instinct or ability, and indeed many of them were devoid of this equipment; but there is little room these days for men lacking the power to evaluate the economic as well as the technical elements of a project. The university training of the engineer has probably given him a grounding in science, technology, ethics, and economics, with perhaps a dash of philosophy, psychology, and hygiene; but it is likewise probable that it has not offered much training in money-making or business method. For this reason it is necessary to state some of the situations in which, as a business man, he will find himself when undertaking the valuation of a property.

The engineer must have the courage of his convictions in every case of mine valuation. Undervaluation due to timidity is almost as bad a blunder as overvaluation due to rashness. Good mines are

rare, and any promising prospect should not be lightly dismissed. The pessimist destroys the honest work of the optimist as well as his rainbow dreams.

A natural feeling of hesitancy comes to the conscientious person as he undertakes his first examination and valuation—a lack of this feeling is a sign of overweening confidence. This same hesitancy, moreover, reappears at every successive job of increasing importance —a sense of helplessness that arises partly from the complexity of the task, partly from the limited time allowed for mine examination. But systematic planning to keep both the engineer and his assistants steadily at work for long hours will accomplish wonders.

Presumably capable engineers, it may be noted, do not always agree in their valuation of the same property. A marked instance is the case of a California mine that was "examined by ten experts, among whom were three succeeding managers of a foreign syndicate, two graduates from Pacific Coast universities, one state senator, and one head assayer for a large California mining corporation";[1] of these, five condemned the mine and five recommended it.

Kinds of properties.—Properties to be valued range through a complete series which may be roughly classified as follows:

Prospective Mines

- Prospects with but little development (say, not more than one hundred feet of opening on a vein)
- Prospects with extended development (say, from one hundred to five hundred feet of opening on a vein)

Developed Mines, but Non-Producing

- With accessible workings
- With inaccessible workings

Producing Mines, Developed and Accessible

- Without reduction plant
- With small reduction plant
- With large plant and heavy production

Cases requiring valuation.—Although the following cases requiring valuation will arise, there is little difference in the principles followed by the engineer.

1. *Valuation for a prospective purchaser, or to negotiate a loan.* The earliest and most frequent need for valuation comes when the

[1] "Enquirer," "Sampling and Assaying," *Min. Sci. Press,* March 16, 1907, p. 336.

property is offered to a possible buyer. Formerly this valuation was usually made by the independent consulting engineer, but the present custom of large mining capitalists and operators is to maintain a permanent staff for valuation work in connection with the acquisition of new mines.

2. *Valuation for a prospective seller.* This case is rare. The seller seldom has any difficulty in placing an exaggerated value on his property, and he generally wants no uncompromising facts to intrude into his dreams.

3. *Valuation and study for the purpose of recommending development, or installation of metallurgical equipment.* This type of valuation occurs most commonly as the ordinary routine work of the staffs of exploration and operating companies. Disputes between the management of a mine and the staff of the reduction works of the same company do occur, and an engineer may be called in to report on the questions involved.

4. *Valuation in the ordinary course of mine operation, to obtain information for routine periodic reports.* This is part of the administrative duty of any well-ordered mine management, and the questions to be answered are almost always stated explicitly.

5. *Valuation for shareholders dissatisfied with the management of their board of directors.* This case is beset with diplomatic difficulties, and the engineer's status is not always a comfortable one; it may bring him into conflict with the mine officials.

6. *Valuation for purposes of governmental taxation.* Appraisal for assessment purposes is a specialized form of valuation, the complexities of which will be hinted in chapter 19, Part Two.

Relations with seller and promoter.—The first contact that the engineer will have with his client—either an individual or the officers of a company, in the usual case—at the beginning of a valuation will be a discussion of the advisability of an extended examination. At the time of negotiating for an option to purchase, the seller makes certain representations as to the value of his property, supporting them with figures furnished by himself or by reports previously made by engineers. From these data alone, inadequate though they may be, the engineer must determine first of all whether it is desirable to make a comprehensive valuation of the mine. Needless to say, most of the projects soon reveal a lack of the minimum requirements that would justify further inquiry; and by a methodical preliminary examination of this sort he may be able to advise against

an exhaustive examination that in many cases might easily cost thousands of dollars and in the end still result in an unfavorable report.

Every new mining venture has disadvantages and troubles to overcome, and it is the duty of the engineer to protect the purchaser by pointing these out to the seller as an argument for modifying terms. If the documents presented apparently indicate no difficulties in operation, the very fact of the absence of such unfavorable factors is a sign that there has probably not been a complete disclosure of the situation. For one thing, a mine with no actual or potential troubles is rarely for sale; the owner himself can work it at a profit.

The first reports on a property usually come to the engineer from the hands of a mine promoter[2] acting as intermediary between seller and buyer. The promoter comes to the meeting full of a fine enthusiasm not unaffected by education in modern selling methods. His attitude is a threat to impartial judgment, for his first purpose is to create a mood of optimism. As a rule, he does not intentionally deceive; but many of his statements are not based on facts, and upon the groundwork of only a few facts he can erect an enticing edifice of fancy. The inexperienced listener, under the spell of such a vision, feels a strong inclination to accept the seller's statements as true; and therein lies the danger. The seller's enthusiasm must not be condemned without qualification, however, for without optimism only a small tonnage of metals would be produced and only a few valuable mines developed. The engineer's function in this situation is to apply the engineering method, to sort the information put before him and classify it into two categories, fact and fancy. The engineer is interested only in fact.

Any man who owns a mine that he really wants to sell should on his own initiative support each of his statements with evidence, frankly presented, or run the risk of falling under suspicion. But too often the engineer must base his preliminary report on evidence that is vague and untrustworthy. The seller is tempted to withhold unfavorable documents. Many of the statements put before the engineer of the prospective purchaser are drawn from tales of old men who have lived all their lives in that one camp, or from books or newspaper articles that may be in error. Even reports by reputable engineers may be so presented as to distort their bearing upon the matter. Not much real information can be obtained from a promoter, who in almost every case has his own information at

[2] For several other phases of the promotion operation, see pp. 248–73, 305–12, and others.

second hand and whose business it is to sell rather than to judge; his rash statements may often be easily disproved through cross-examination.

If such a promoter makes a successful sale every two or three years, he is amply rewarded; for this reason he takes up a great variety of propositions that have little demonstrable merit, and if one out of a hundred succeeds he can win a good living. Incidentally, some types of unworthy promoters derive additional income from handling shady mining shares in small quantities.

Mine promotion, like many another pursuit, is a proper activity if carried on honestly. Promoters of business enterprises form a legitimate and necessary class in modern affairs, and it is through abuse of their opportunities that the term "promoter" has in certain quarters acquired opprobrium. The French word "entrepreneur," almost exactly equivalent to the English "promoter," has not been branded with stigma.

The promoter's profit, at the early stage of the business here visualized, comes from a commission on sales, and these commissions are often very large—in one exceptional case it was $900,000. In the early promotional phases of a mining business every man who handles the reports, or who passes the promoter along, or who gives an introduction, tacks a commission on the purchase price. The first questions put to the promoter should be directed to find out who are the intermediaries between him and the actual owner. He may state that there are none, and yet a dozen may be revealed in the end. The engineer acting on behalf of a purchaser should find out who is to get the full purchase price. If the person presenting the proposal shows any reluctance to give details of the distribution of the price, it is good evidence that the engineer should penetrate deeper into the matter and find out what portion of the proposed purchase price the promoter and his associates are to receive and what they have done to deserve it. By correspondence with the actual seller, the exact price he is to receive may be discovered. It is the proper function of the engineer to help his employer or client to reduce the price asked by eliminating intermediaries who have performed no tangible service and are not entitled to any reward. With the owner's response in hand, the question of commissions may be dealt with more fully. In the course of this correspondence the engineer should also endeavor to indicate to the owner the amount that would be a fair price for the property, a price generally much below that asked by either the seller or the promoter.

Under no circumstances should a preliminary payment be made on the sole basis of statements made by owner or promoter. If the owner's statements are true—as he will stoutly maintain—then he need have no fear that he will miss a sale by giving the prospective buyer time and evidence enough to reach a conclusion as to value. Profitable mines are rare, and capitalists are only too anxious to discover a mine with glowing prospects.

The position of the engineer at the early stages of negotiation is similar to that of the judge on the bench. From a mass of appeals and arguments, based on highly-colored hopes and leading to false deductions, he must separate vital facts to guide his future decision. Optimism, as has been said, may be given somewhat freer scope at this early stage than later, for in general only the cost of examination is risked. If greater risk is demanded, or if unreasonable haste is urged, it is safe to ask the seller to seek a buyer elsewhere.

If an offer is declined without the formality of sampling or a preliminary first-hand inspection, harsh words from the disappointed seller may be answered by pointing out that experience shows an unfavorable report to be usual. An exploration company of London had 1,400 properties offered to it in one year, none of which were accepted. Records of several other exploration companies show a total of 4,093 mines offered and eight purchased, or about one in five hundred.[3]

The preliminary report.—A preliminary investigation, then, should be made to discover any factors that will at once obviate the need for further consideration of the property offered for sale. A brief examination of the data presented will often show that some particular condition will so limit the project as to make further investigation unnecessary. Inaccessibility; high capital expenditure; lack of power, fuel, or supplies; signs of "petering out"; unsavory history; exorbitant price; scope for only a small scale of operation; unstable government; excessive taxation; impossible climatic or labor conditions—any of these may on occasion preclude any further consideration by the prospective purchaser; yet cases are known in which engineers of good standing have mistakenly recommended the purchase of mines having, for example, insufficient water resources or containing ore that could not be reduced by known metallurgical processes. As the years go by, these cases are happily being reduced in number.

[3] Pickering, J. C., *Engineering Analysis of a Mining Share.*

The effect of climate must be carefully considered. In such unhealthy regions as West Africa, Nicaragua, and elsewhere, white men cannot work more than one or two years without returning to the temperate zone for several months of recuperation; these compulsory vacations add greatly to the expense of mining operations. And in the "verrugas" section of Peru, the high death rate from that curious disease might render mining impossible.

The stability of government in the area where the enterprise is proposed to be carried on is a pertinent factor in the valuation. Large areas of the globe are closed to enterprise and capital venture because of instability of government and hostility to the profit system.

If an exorbitant asking price is not capable of adjustment, or if sufficient capital is not available, no engineering report can possibly bring together seller and client.

Every prospector and nearly every seller dreams that his ore will grow richer and his lode wider as his hole in the ground deepens; but the opposite is more frequently true, and many mines become poorer the deeper they are worked.

One cannot rightly expect that the future production of an old mine will be as good as its past records, although the evidence of past performance is an important guide to future possibilities. It is not reasonable to expect to mine ore of any better grade in the future than in the past; on the contrary, the best ore has usually been mined first.

There are few mines to be valued of which no maps are available; all such maps must be studied and compared, and discrepancies must be reconciled. Peele's *Handbook* is a good guide to the study of maps.

The depth attained by the workings may be economically prohibitive if the cost of extracting the ore at that point is greater than its market value. Moreover, the depth at which a mine may be worked is also dependent in some cases upon the prevailing temperature. Men cannot ordinarily work at temperatures above 150° F. This was exceeded slightly at the Comstock mines, but since work could go on for a few minutes only, the expense was startling. Increase of temperature with depth varies widely in different places,[4] from an exceptional case in a Belgian mine where an increase of one degree F. occurred for every 22 feet, to a Rand mine where an increase of one degree F. occurred for every 376 feet. Tempera-

[4] Peele, Robert, *Mining Engineers' Handbook*, 2d ed., p. 1568.

ture may vary greatly in the same mine, depending on local conditions. If some condition such as hot springs causes a great increase in temperature, the working limit may be reached at only 500 feet, although mines are being worked at 7,000 feet on the incline without restriction caused by excessive temperature.

The investigation of the titles to a mining property can safely be turned over to a lawyer or a title-abstract firm or expert. The engineer will supply such surveys of the property as will co-ordinate the property lines with the descriptions of locations in patents and deeds. The legal adviser should be familiar with local procedure and special mining legislation.

Early development work on mines is always done with cheap equipment. This equipment, even if not completely worn out with use, is of little value beyond the initial period of the venture, and should rarely be taken into account as an asset, since the cost of shipping is usually greater than the salvage value.

No sensible person would suggest the purchase of a mining property without thorough inspection and sampling by a competent engineer. The purpose of the preliminary investigation of the data here described, which is more often than not based upon second-hand information, is merely *to determine whether an extensive sampling and examination is justified.* In arriving at this tentative valuation the engineer employs the same general principles that hold for the extensive valuation described in the following chapters, except that the decision upon various factors is deferred until confirmed by examination. It would be impossible to give every clamant seller the privilege of an expensive examination; but it is perfectly possible to weed out the worthy prospects by judgment solely on their stated values. The reliability of most mine data can be tested by internal evidence. Then, too, if the property has been on the market before, enlightening records of the transaction are almost always to be found in reports of other engineers, technical periodicals, professional proceedings, and the like. In almost every large city, and especially in such financial centers as London, New York, and San Francisco, thousands of mining reports are in circulation; in the course of years, several reports on the same mine may come into the engineer's hands. Since the information contained in them may reveal much concerning not only the property, but the reporting engineer and the sellers and promoters as well, it is an excellent practice to make brief abstracts of these reports. The following imaginary abstract will give a good standard form to follow:

(Indexed under *metal:* Gold
reporting engineer: Capistrano
promoter: Roe, Richard)

NAME OF PROPERTY: San Timoteo Mines

SITUATION: Mexico, State of Chiapas, District of Montebello. Near town of Tirepeti. Twenty miles from railway; five miles wagon-road, rest bad mule trail. Altitude, 6,000 feet

OREBODY: Gold-quartz vein; 1,000,000 tons developed by tunnels; average grade, $10; profits estimated at $5,000,000

CAPITAL NEEDED: $300,000. For 50-stamp mill, wagon-road, mine development

TERMS: Cash $250,000 and one-fourth of shares. Commission allowed, ten (10) per cent

REASON FOR SELLING: Former owner, a rich tobacco manufacturer, died recently and estate in hands of widow, sole legatee

REPORT: By Juan Capistrano. Brought to me by Richard Roe, May 1922

SENT TO: Mexican Exploration Co., June 5, 1922. "Not interested." A. C. Nonney, July 5, 1922. Engineer sent August 1922; unfavorable report

It is worth pointing out that when reading a report no small or seemingly uninteresting paragraph should be skipped. The information given may be vital. The training in the engineering method given in the university is wasted if it does not result in the endeavor to observe and analyze every fact bearing on a situation.

If a favorable preliminary report is made and a thorough investigation is called for, consideration must be given to the time and money that will be needed to conduct this examination. At this stage a favorable opportunity is presented for further negotiations to lower the price and adjust any onerous conditions of the option offered.

Time and expense of examination.—One engineer with suitable help can take about ten samples in a day. This number of samples in an ordinary case would cover fifty to one hundred feet of workings. A mine of even moderate size, having 6,000 feet of exposed ore to sample, would thus take two to four months with one crew. The time and expense of an examination of a medium-sized property might easily be of the following order:[5]

[5] Note that these are prewar figures.

Sampling:		
Chief engineer, 30 days at $50	$1,500	
Assistant, 30 days at $20	600	
5 miners, 30 days at $5	750	
5 laborers for crushing, etc., 30 days at $4	600	
	——	$3,450
Assays:		
600 runs at $3		1,800
Maps:		
Assistant, 30 days at $20	$600	
Chainman, 30 days at $5	150	
Draftsman, 30 days at $10	300	
	——	1,050
Computations:		
Chief engineer, 30 days at $50	$1,500	
2 assistants, 30 days at $20	1,200	
	——	2,700
Total		$9,000

Expert advice.—In the course of a large and important examination, vital questions may arise, the answers to which lie outside the engineer's training and experience. For example, the wisdom of the purchase of a property may depend on the solution of some obscure problem in economic geology, or one in the metallurgy of complex ores—problems that all mining engineers may not have the proper training to solve. In such cases, the engineer should frankly advise his client that the valuation of the property depends upon such points, call attention to his own limitations, advise the sending of experts capable of giving a sound opinion, and then await instructions.

Speculative mines and the risk in mining.—The intrinsic value of an ore deposit may be high, but if there are any limiting factors that preclude normal production, development, or sale, the value of the mine lies within a more or less wide margin of risk. The opening of new markets, increasing scarcity of metal, improved transportation, application of better methods, a drive to establish new uses for the product or to meet competition—in fact, any improvement in the situation in the course of time—might convert speculative value into actual value.

The estimated future profit, under normally favorable conditions, from the exposed and sampled ore may be called the basic value of a mine. To this is always added a speculative value that is the product of risk factors such as probable extension of ore, fluctuations in price,

new metallurgical developments, or new conditions affecting costs and revenues. Highly developed properties can naturally be valued closely, but although the risk is lessened the margin of profit must nevertheless be cautiously determined. When the margin of speculation is great, however, and the stakes at hazard are also great, the price should be correspondingly low and may be merely nominal.

The element of risk in the mining business, although it can be discounted by shrewd valuation and efficient management, is greater, it must be admitted, than that in any other industry. For this reason the industry of mining has often been brought into disrepute by unprincipled exploiters preying upon the gambling instincts of ignorant possessors of money. So glorious is the age-old myth of Eldorado that there is no lack of men and women who are inclined to mining speculation, and the occasional "big strike," magnified and publicized without end, serves to give added luster to the never-dying dream. It must be pointed out, however, that it is the lure of enormous profits that keeps the mine-hunting game going. If it were not for this lure, if the mining business yielded no higher profits than ordinary commerce or trade, the risks and losses in mining would soon drive out capital, and our civilization would crumble for lack of metals to hold it together; and so our civilization may be said with some truth to be based on an iridescent dream. Those investors seeking steady return and security may always purchase government bonds. The more venturesome investor, if he wishes to protect his capital as much as possible from the hazards of mining, must be prepared to study the factors influencing mining values, to rely upon the knowledge of reputable engineers, and to reduce as much as lies within his power the unknown elements that may affect his investment. It may be said that reliable investment companies are more and more frequently encouraging the investor to demand the essential facts concerning the values of various properties and otherwise to avoid the more obvious wiles of the trickster. Moreover, engineers of high integrity and technical capacity are taking increasingly greater part in the management of mining enterprises, and thus can insist upon scientific valuation that may limit to some extent the degree of hazard in mining finance.

Why mines close.—A large proportion of the mines valued by the engineer are in a shut-down condition. The reason for the closing of such a mine is a pertinent factor in its valuation. Among these reasons are the following, some of which are not to the advantage of the seller to disclose.

1. *Change in nature of ore with depth.* As a mine is worked to greater depth, the grade of ore may decrease in value, or the problems of treating the ore may become more difficult. The latter case would require an expensive change in treatment plant, and thus would add to the cost of extracting the metal. This type of mine is represented, for example, by a large group of abandoned Mexican, Central American, and South American "antiguas."

2. *Exhaustion of the ore.* This may result from: (*a*) pinching out of the vein, as often occurs in granite areas; (*b*) faulting, or loss of the vein, such as has occurred in certain Nevada mines; (*c*) "picking out the eyes," or mining of all high-grade spots; or (*d*) complete exhaustion of ore, when mines are entirely worked out.

3. *Shift in price of metals.* This is responsible for the closing of a great many mines, particularly those producing base metals. Naturally, gold mines would not be affected by this factor, since the price of gold is normally fixed by law, and may even sell at a premium; though a gradual increase in the price of labor and supplies may ultimately have the same effect as a drop in the price of the metal.

4. *Influx of water.* The flooding of a mine, or increased depth, may require, for the installation of pumping equipment, a large outlay which could not be justified at current metal prices. Mines have also closed because of a breakdown in the pumping machinery and a prohibitive cost of recovering submerged pumps.

5. *Caving of large stopes or levels.* It is possible to wreck a mine completely by careless timbering or filling of stopes, and some mines have remained closed after such an accident.

6. *Bad management.* This is sometimes given as a reason for a shutdown, but can generally be viewed with skepticism.

7. *Need to convert property into other forms of capital.* Ill health of the owner may be such a cause, although it is perhaps not so frequent as some sellers would have one believe.

8. *Prohibitive depth.* Although the quality of the ore may not change, the depth at which it is worked may be so great that the metal produced will not pay for the costs of operation, unless a large amount of additional capital is raised.

9. *Premature abandonment.* Some mines have been assumed to be worked out when further geological exploration would have shown that it would have been profitable to continue operations.

10. *Increase in taxes, or change in legislative measures.* Oppressive taxation, compensation insurance, ownership regulations, or tariffs may make mining investments in certain countries extremely

insecure or unprofitable and result in shutting down. Subsequent changes in such legislation may allow the mines to open again.

11. *Exhaustion of capital.* If the management has failed to set aside a fund sufficient to continue operations through lean periods, it will be necessary for them to seek additional capital or to sell the property. Shareholders may refuse to pay assessments, and a legal squabble to dispossess them of their claims may tie up operations.

Some of these reasons why mines are on the market may be merely temporary, and any change in conditions might easily put the property back into the paying class.

Mines that are in operation and are producing are not often found on the market. If a mine is barely paying expenses—or even running at a slight loss if the owner can afford to do so—it may still be considered a hopeful investment, since the chance of striking rich ore will always appeal to the speculative instinct. The very fact that a mine is for sale should put the careful engineer on guard and lead him to search diligently for the real reason why it is on the market.

FACTORS IN VALUATION

As has been stated, an absolutely accurate valuation of any mine is impossible because of the variety, intangibility, and irreducibility of the many factors involved. Advantage may be derived, however, from stating some of the more obvious of these factors; for this reason the following list is offered, not without some diffidence, merely to indicate that these factors do exist. Some of them will later be treated in the detail they deserve; others are mentioned in passing and their evaluation must be left to the common sense and the experience of the engineer.

Factors listed.—The factors in valuation of a mine may arbitrarily be listed and grouped as follows:

Physical and Geographical

1. Position and accessibility
   - *a*) Distance from nearest town
   - *b*) Distance from railway
   - *c*) Distance from smelter or market
   - *d*) Condition of roads and suitability for various types of transportation
2. Climate
   - *a*) Effect of seasonal variation on operations
   - *b*) Effect on health (altitude, health conditions, local disease risks, etc.)

3. Availability of power
4. Availability of supplies (water, fuel, timber, etc.)
5. Topography (limiting structural features, liability to flooding, etc.)
6. Transportation situation: cost, safety, and reliability regarding
    a) Transportation of ore
    b) Transportation of concentrate or bullion (bandits)
    c) Transportation of supplies and equipment
7. Size of property
8. Depth of workings; temperature at depth
9. Amount of water and pumping cost

Mineralogical and Metallurgical

1. Kind of metal or metals present
2. Quantity of metal per ton; "high-grade" vs. "low-grade" ores
3. Geology of property and district
4. Ore
    a) Geology of ore
    b) Size of deposit and probable extension, as indicated by sampling
    c) Associated minerals (refractory ores)
    d) Accessibility of ore
5. Present method of treatment and metallurgical difficulties
6. Type of operation recommended

Political and Social

1. Labor
    a) Availability of labor supply
    b) Local conditions and laws
2. Laws regarding taxes, duties, workmen's compensation, contracts, etc.
3. Stability of government
4. Attitude of local population toward project

Historical

1. History of property
    a) Date of first development
    b) Amount and grade of ore handled; mine reports; sale of product
    c) Previous engineering reports
    d) Balance sheets and dividends; financial history and accounts
    e) Previous sales of property
    f) Previous metallurgical history
    g) Reputation of seller
    h) Reason why mine is on market
    i) Present stage of development; description of plant and equipment; operating methods used
    j) Safety record
2. Histories of neighboring mines in operation, especially concerning size, consistency, and changes with depth of deposits, and pumping charges

Legal

1. Soundness of title, present and future
2. Terms of sale
3. Existing contracts of seller, especially smelter contracts

Financial

1. Purchase price
2. Terms of payment
3. Amount of capital required for development, equipment, and operation
4. Estimated future financial conditions
5. Proposed financial organization
6. Estimated future price of metal
7. Value of plant at present stage of development
8. Costs
    a) Present average cost of production
    b) Estimated average future cost of production

Main lines of valuation process.—After the preliminary investigation has revealed the desirability of further examination, and the general information bearing on valuation is supplied, the course of the engineer's investigation will follow the main lines set out below. It goes without saying that these lines should be followed simultaneously. It is a waste of time and money to take a thousand samples from a mine and then find the costs of operation are prohibitive, or that the metal cannot profitably be marketed, or that the titles are defective.

The main lines to be followed in the valuation process—assuming that the titles to the property are under investigation—are briefly as follows:

1. The sampling of the deposit and the valuation of known ore
2. The estimation of proved, probable, and prospective ore
3. The economic geology of the deposit
4. The metallurgical treatment of the ore
5. The calculation of percentage of recovery
6. The calculation of costs of production, reduction, and distribution
7. The estimation of market price of the metal
8. The financial control of the enterprise

The careful integration of the results of such studies will enable the soundest possible valuation to be made; and the results and conclusions should be set forth clearly and precisely in the engineer's report.

Epitome of valuation method.—The progress of these various lines of investigation, which will form the subjects of the remain-

ing chapters in Part One of this book, may be epitomized in another way:

1. *Determination of revenue to be derived from the ore in the mine.* The engineer will take a sufficient number of samples of ore at the various developed openings to enable him to prepare a reliable map of the workings, showing pay-shoot trends, measurements, and assay values. The ore deposit may be segregated into blocks according to relative risk in continuity, considered in the light of the economic geology of the deposit. From the data thus collected, he will calculate the estimated volume and weight of all ore in the property that can reasonably be assumed to exist. The total tonnage thus calculated, multiplied by the determined average value of the ore per ton, will yield the gross value of the ore in the property.

2. *Determination of expenditures that must be made to operate the mine.* From the gross value of the ore must be deducted the large sum representing cost of mining, treatment, marketing, management, etc., and losses in recovery. The resulting amount will be a gross, or operating, profit or loss to be expected under the proposed program of development.

3. *Determination of present value of the property.* The operating profit to be made from the business is not by any means the value of the mine. Provision must be made for the purchase, development, and equipment of the property, and the purchaser should receive a substantial profit. The bearing of these capital expenditures on the present value of the mine is discussed in detail in chapter 8.

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Chapter 3

Sampling

The first activity in the course of a mine valuation is the sampling of the ore deposits, in order to obtain facts that will enable the engineer to estimate the distribution, quantity, and mineral associations of the metals or minerals present in the known orebodies, as well as in the probable or possible extensions of ore.

GENERAL CONSIDERATIONS

Theory of sampling.—An ideal sample of an ore would be a small portion that would be exactly representative of the larger section under examination. Since metals are rarely distributed by nature in an even manner it is impossible to obtain mathematically exact samples. Correct sampling procedure aims to secure specimens of the orebody large enough to yield results, within reasonable limits of error, that may form the basis of reliable maximal and minimal estimates of value. The purpose of sampling is to give a quantitative value to one of the main factors in the engineering problem.

Importance of sampling.—Careful, precise sampling is the most important factor in an extended valuation. An inaccurate sample is worse than none, since it inevitably leads to false conclusions.

Size of sample.—The size of a sample to be taken is relative, and must be determined by judgment, considering the end the sampler wishes to attain. The sample may vary from a few pounds of ore chipped from a particular site to thousands of tons covering a large area of erratic or low-grade metallic ores. Since most metals, especially gold and silver, are distributed in an irregular manner through the gangue, and since the gangue is frequently harder and more solid than the more highly mineralized parts of the lode, it generally holds that any sample taking an excessive proportion of either fine or coarse particles will not truly represent the lot.

Types of samples.—Some form of sampling occurs at every stage of the process of extracting and reducing metals. The pick-samples

of the prospector or explorer, the cores of drilling machines, the crude "grab samples," fractional selection by taking every second or tenth shovelful of a consignment of ore, the automatic diversion by machinery of a portion of a stream of ore, the sampling of concentrates and even bars of bullion to determine metal percentage, and the large-scale sampling by mill runs—all these are one form or another of the process of estimating the value of the whole from the part, and usually enter into the routine business of mining, shipping, and smelting.

The samples taken for the valuation of a mining property are relatively small in amount compared with samples taken for the purpose of controlling development and production. These consist of chips taken by hand, with pick or moil or with other portable equipment such as a "jack-hammer," in channels at defined intervals along the exposed face of the underground workings. Most samples will be taken from such a channel or groove about one inch deep and two to five inches wide, cut across the face of ore it is proposed to sample. The groove should be as nearly as possible of uniform depth and width throughout its length, for each sample; but the grooves for different samples can vary in depth and width among themselves.

Equipment.—One advantage of the careful *preliminary* study of all the data of a mining property prescribed in the previous chapter is that it enables the engineer to estimate the size of the task and the staff and equipment necessary. Everything that he will need for the work of valuation should be provided before the actual work begins. The type and amount of equipment will vary with the particular undertaking. Herzig[1] gives an extended list and description of sampling equipment. From this list the following may be selected as absolutely essential: canvas sheets, sampling buckets, large sacks or boxes with locks, clean sample bags, twine, wax, seals, linen shipping tags, pencils (plain and colored), notebooks, pocket compass, aneroid barometer, and measuring tape. If assaying on the spot is contemplated, a full assay outfit should be included.

If the mine is in operation, the following items will be at the mine and need not be taken: hammers and picks, moils, gads, drills, miner's picks, shovels, brooms, brushes, transit, whitewash, and mechanical dividing sampler. All these articles seem indispensable, and yet important mine reconnaissances have been made with no more tools than a pick and shovel.

[1] Herzig, C. S., *Mine Sampling and Valuing*, pp. 19–27.

Assistance.—Even the smallest mine examination requires one assistant to the engineer, and larger ones call for several. If this assistant is personally known to the engineer and is brought with him the possibility of subornation by the seller or his agents, bent on fraud, is vastly lessened. The best of all junior assistants is a university student: he will be keen to learn; his professional ethical standard will be much superior to that of the average miner; he will understand the rudiments, as well as the importance, of accurate valuation; and he can take turns with the examining engineer at the hard physical work of sample-cutting and in the important duty of guarding the samples. However, such an assistant should not be intrusted with more responsibility than that for which his experience qualifies him. He should never be sent into the field alone to make more than the merest rough survey, and his work should be checked by the senior engineer at each point. If the engineer is not qualified to do so, one or more of his assistants should be experienced in assaying, surveying, and making geologic maps.

If a large number of samples are to be taken, the engineer is obliged to intrust most of their cutting, care, treatment, and assaying to his helpers. These helpers can be organized into parties, but in no case should any party be left without the presence of a dependable subordinate unless precautions are taken by some of the methods, later to be outlined, to detect fraud or carelessness; it is much more satisfactory, however, to have an assistant always present. In the actual cutting of samples one assistant can watch two cutting-crews if they are working close together, but their work must not be accepted without some subsequent check. The assistant's major duty at such a time will be the sacking and marking of the samples, the careful study of the orebody, the making of geologic and mineralogic sketches, and recording data in the field book.

Maps and assay plans.—All the data collected during an examination should be entered daily on maps and assay plans or on clean record sheets, and not merely in the field notebooks. Failure to record the work promptly leads to endless confusion and makes the whole examination a burden; but if the record is kept up to date, it is pleasurable as well as profitable.

The working maps should consist of horizontal projections of the levels, made in pencil on cross-section paper. If the vein is steep, it will be necessary to use separate sheets for the different levels, or at least to displace them to such a distance from the true projection that they will not be superimposed one upon another. These

projections are especially useful for showing the detailed structure of the vein, the position of the sampling grooves, the relations of the rock walls, and all other geologic data. In addition to this horizontal projection, longitudinal sections or projections should be made as the work progresses, upon which will be entered all widths and assay results.

These maps permit tracing of the boundaries of the ore shoots and outlining the different blocks of ore. Frequently, map cross-sections should be made at various points, through raises and winzes, to show the relations of the different levels and the geological structure. All working maps should be drawn in pencil, leaving the making of finished maps until the sampling is complete and work has begun on the report.

The basis of mine valuation is a series of measurements and weights. To obtain these, a survey must be made of the mine; the survey records and the map based upon them must be accurate, not merely to set out sampling results more clearly, but often to give clues to the economic geology of the deposit also. The mine map must therefore often be a geologic map as well as an assay plan, from the sections of which a complete picture of conditions may be constructed. Mining literature affords many instances of mines that were incorrectly reported upon because of certain misunderstood complexities of geologic structure. Accurate map-making is therefore an important part of mine examination.

Notes.—It is good practice to allow about one page of the notebook for each sample. Put the number of the sample at the top of the page, and show complete data beneath: distance from a fixed point, width, depth, formation of section, true width of vein, by whom taken, when, how, and all other points of interest. One or more sketches of the vein and workings, and of the position of the sample taken, should go on the same page. When sampling drive faces, cross-cuts, or raises, one sketch should represent a hypothetical vertical cross-section of the vein at the groove, with exact measurements showing the position of groove and the manner in which the vein is divided into separate samples. Another sketch might be a horizontal projection of the vein in the vicinity of the groove; this is for the purpose of recording the major portion of the geologic evidence. These horizontal sketches, when joined together, will give a complete geologic map of the mine. After the groove has been cut and the sample is in the sample bag, the large amount of information that has been gained by intimate contact with that sample should

be set down in the notebook. On the proper page, under the sample number, any geologic evidence of interest should be recorded. It may be of assistance to record such minor items as the length of time taken in cutting the sample. The measurements of hard and soft, or rich and poor, streaks should be noted, if sampled separately.

It is a good plan to enter in the field notes, at the time of taking the samples, rough computations of value from the appearance of the material sampled; this may prove useful if "salting" of samples is attempted.

Field notes can never be too complete. The care and disposition of the data collected in the field book and on the maps are more fully discussed in chapter 4, under the subheading "Calculations from Sampling."

RECONNAISSANCE

Preliminary survey.—The engineer undertaking the valuation of a mine should conduct a preliminary inspection upon which to base his campaign. Indeed, the results of such a survey may indicate that no further examination is necessary. During his first visit to the workings the engineer should ask to see the richest ore; a study of this supposedly rich ore may reveal that an extended valuation is not required.

Granting that further examination is needed, however, the engineer should discover the salient points that will influence his later procedure and note the general lie of the land. Much information of value can be obtained from resident officials and miners, from existing maps, and from inspection of workings, features of topography, and ore and waste dumps. The findings of this preliminary survey will indicate the most expedient course of procedure that the engineer and his assistants should follow.

The examining engineer upon arrival at the mine should establish friendly relations with the staff. One hardly needs to point out that he should be very careful not to antagonize the men he meets by assuming airs of superiority. Since he represents important capitalists, his reception is sure to be cordial; and by cultivating these amiable relations he is certain to obtain valuable information for immediate and future use. One of his best means of eliciting information from others is to give all the information that he can about himself and his business, without, of course, violating confidences. Frankness is usually reciprocated.

A resident engineer or foreman will accompany him during his

first examination of all the workings, but later tours of inspection and sampling should be made alone or attended only by his assistants. The engineer should insist on seeing every part of the mine, notably the bottom level and any parts which may be blocked off. If the property is a small prospect, this general examination may not take more than an hour; larger mines may require two or three days' reconnaissance for the first inspection. During such inspection the attitude of the engineer should be entirely receptive, and never outspokenly critical of existing operations.

Careful notes should be made of all information received, and statements should be checked, as far as possible, at the time, as well as recorded for future detailed examination. For reconnaissance work a hand pick is most useful, but this implement, although used by some engineers for the purpose, is not adapted to sampling hard ores, though useful for soft ores and for alluvial. With map and pick in hand, the engineer should scrutinize the workings and minutely examine the vein structure. Care must be taken to see that the map represents with a fair degree of accuracy the actual underground geography of the mine. If the mine is a prospect with little development, it is likely that there will be no map; in such a case, a map must be made. Copies of all important existing maps should be obtained to include with the formal report that will later be submitted to the client.

Critical portions.—During the course of acquiring a general idea of the geography and economic geology of the mine by this reconnaissance, knowledge will be gained as to the parts that will be particularly important in a valuation. These critical portions will often be found at the ends of drifts, and especially at the bottom of the mine. At these points must be secured the evidence upon which to base an opinion on probable extension of ore, laterally and with depth; therefore, it is often at these points that the work of sampling should begin. The bottom level is in most cases a highly critical region because, if the prospects there are not favorable, the life of the mine may be so limited that the property is not worth the price asked. In such a case, the sampling of all the upper levels is useless. Even if the vendor's statements on the value of the ore in these upper levels are correct, it can sometimes be demonstrated from the results of examinations on the bottom and other critical portions that the future output cannot repay the asking price. For this reason, the sampling of critical portions should begin at the earliest possible moment; and if the engineer determines that the property

will not justify the price, he should advise his client to withdraw or to negotiate for a reduction in price, before proceeding with the expense of a full examination.

Plan of campaign.—When the main features of the sampling problem have been ascertained during the preliminary survey, the engineer is in a position to decide which sections are to be sampled and what procedure to use, and to apportion and schedule the work of himself and his assistants. He will reveal his qualities of generalship by the systematic way in which the information obtained is employed in organizing his forces for accurate and efficient sampling.

Course of sampling.—It may be mentioned here that, once sampling has started—at the end of some convenient level or at some critical section of the mine—it should continue on its regular, predetermined course until completed. Under no circumstances should the sampler pass from one part of the mine to another, taking samples haphazard.

Neither is it wise to have more than one or two sampling places being worked on at the same time. Such a precaution may seem unduly elaborate, but any method of taking samples that places a premium upon speed rather than accuracy is sure to cause grave trouble sooner or later. The final valuation analysis may often be seen, after examination is complete, to depend upon a very few critical samples. If these samples are mixed or interchanged with others, or otherwise lose their identity; or if there is any doubt that they were carefully taken, one can readily picture the disaster that might follow. The extra time spent in the practice of a careful method is a small price to pay for insurance against errors of this sort.

It may be necessary, when following the course laid out for sampling, to take down a set of timbers in order to sample the points to which the sections or grooves are measured. This is often a small matter, and should not stand in the way of taking a sample in the proper place. The mine owner should remove the timber cheerfully, and a strong refusal may well raise a prejudice in the mind of the engineer. The course laid out for sampling should be cleared even if the timbers are covered by lagging and filling. However, if it is absolutely impossible to remove the timbers, and no equally effective sampling position is available, two lines of action are open: the vein may be assumed to be absolutely barren at this interval, or it may be given some value proportionate to the values on each side, although there are grave risks involved in either procedure.

Marking places for samples. — The decision upon where the samples are to be taken, and the width and length of the cut, must not be delegated to anyone; the engineer himself must mark the place in the mine where each sample is to be taken. Many engineers paint on the rock the position of the sample and its serial number, so that it can be easily found for resampling; this method saves considerable labor, but it places too much knowledge at the command of fraudulently inclined vendors. A better method is to make a list of the samples to be taken, locating them by measurement from some fixed point in the mine, and giving the subordinate all this information, including the serial number of the sample. If necessary, the position of the sample may be marked with whitewash, but not the serial number. One advantage of measuring off the places for the grooves and marking them on the rock is that it reduces the error resulting from the human tendency to pick out a good place for a sample. If the vein twists and turns, the measurements between samples must be made along the middle of the opening, and the dip will govern the direction of the groove.

A sampling groove should never, unless it is absolutely unavoidable, be run along the floor of the working, and then only after most careful cleaning and trenching below all irregularities in it. The reason for this is easily seen. Rock broken from the face—commonly waste, but in wide lodes often ore—is used to level the floor. Fine material, frequently higher than normal grade, fills the irregularities in the floor and thus would in many cases enrich any sample unduly. If waste, however, is used for leveling the floor, it would impoverish the sample.

Width sampled.—The theory upon which the taking of samples is based is that the values are equally distributed in the portion sampled, or in certain portions of the vein; but since this is rarely the case, various devices must be used to overcome the irregularity in the distribution of values. Geological considerations make it plain that, to do so, a sample should nearly always be taken roughly at right angles to the dip and strike.

In the study of ore deposits it is of great value to learn the distribution of the rich and the poor portions, and these should be sampled separately. In the examination of a Korean gold mine the examining engineer, who had neglected to win the sympathy of the manager, took his sample for the full width of the vein and found it unprofitable; had he sampled separately the four feet of the vein next to the hanging wall, he would have found it rich enough to

pay when worked alone and would have advised his clients to buy the mine.

The samples are usually taken by cutting a groove in the entire width of the vein, but the material coming from the groove may be divided into two or more separate samples.

It should be noted that high-grade ore and rich streaks in a vein are generally softer than surrounding portions, and the natural tendency is for the softer ore to shatter more; hence, a larger portion of the rich streak than is warranted is likely to be included. It is very important, therefore, to guard against error through the inclusion of too large a proportion of rich mineral, such, for example, as silver sulphide or rich gold ore, from these high-grade streaks. If the vein is narrow—under four feet wide, say—only the actual width of the vein should be sampled. Later, the engineer should allow mathematically in his calculations for whatever proportion of barren rock he thinks necessary to make up the proper stoping width or to allow for dilution; but he should not make the error of actually including barren rock in his ore sample. On the other hand, he should frequently take samples of the barren, or supposedly barren, wall rock by itself. There have been mines in which the apparently barren wall rock was in reality of far greater value than the vein. A fairly good rule is not to put more than about four to six feet of groove material into any one sample. If the vein-width is greater than this, separate it to give two or more samples by dividing it at some convenient point, if possible where there is an alteration in the mineralogic content. However, in wide orebodies, especially when the metal or mineral contents are fairly uniformly distributed, samples may cover wider sections.

Determination of true width of vein.—It is not always easy, when underground, to measure the true width or thickness of the vein sampled. This true width does not always correspond to the length of the groove cut, except in those rare cases where the groove is exactly at right angles to the dip and strike of the vein.

Since it is necessary to set down, as a part of the data accompanying the sample, not only the width sampled but also the total width of the vein at the point where the groove was cut, one is often obliged to calculate this true width from information secured at some distance from the sample, for at the point of sampling the walls may be all solid ore, with no country rock showing. This procedure assumes that the vein is fairly regular and does not vary greatly in thickness in short distances. It is frequently a great help

to stretch, from a nail driven overhead, a string parallel to the dip and at right angles to the strike; a measurement of the vein taken at right angles to this string will give the true width. If the dip of the vein is regular, a large wooden triangle having the same angle as the dip of the vein will be found very useful. By using a compass and a level, the triangle may be oriented and thus give the true dip.

If both walls of the vein are not exposed it will of course be impossible to measure the true width, and in such a case a crosscut must be driven to determine the extent of the vein, and permit sampling of the whole of it.

The length of the sample cut must be at once measured or calculated and set down in a notebook when the section is being sampled. It is bad practice to leave the determination of the true width of the orebody until the engineer has gone away and perhaps forgotten to take all the observations he will need.

The true width may also be found by a simple mathematical formula[2] where

h = horizontal width
w = the true width
a = the angle of dip

Then

$$h = \frac{w}{\sin a} \text{ or } w = h \sin a.$$

In this simple formula the angle a is known from previous observations and the horizontal width sampled can be measured by the use of a level. This leaves only w to determine. It is important to note that in the use of this formula it is necessary to be sure that the horizontal width is also measured at right angles to the strike.

It is better in many cases to cut away the wall in order to have a proper cross-section of the vein at right angles to the dip, rather than try to make corrections based on the dip and strike determined at some distance away from the sample (see Fig. 1, p. 50). Anaconda mining engineers, in order to arrive at the true width of a vein, measure width normal to the dip and multiply this figure by the vertical height of the block.

As a general rule the groove should be divided into as many samples as there are mineralogic bands in the vein. When a groove is divided into two or more samples, the average assay of the whole will be calculated by the method described later.

[2] Herzig, C. S., *Mine Sampling and Valuing*, pp. 42–43.

There are a few further points which may on occasion be considered in connection with widths of samples and their distances apart. In Burnham's *Modern Mine Valuation* is a mathematical discussion of these matters, wherein trigonometry and calculus are employed to a great extent. This mathematical argument, however, is abstruse, and the young engineer can be grounded in the principles underlying mine valuation without recourse to such complicated mathematical formulas. Later in his career, when he has the background of professional experience, the engineer can and perhaps will read Burnham with understanding and with profit.

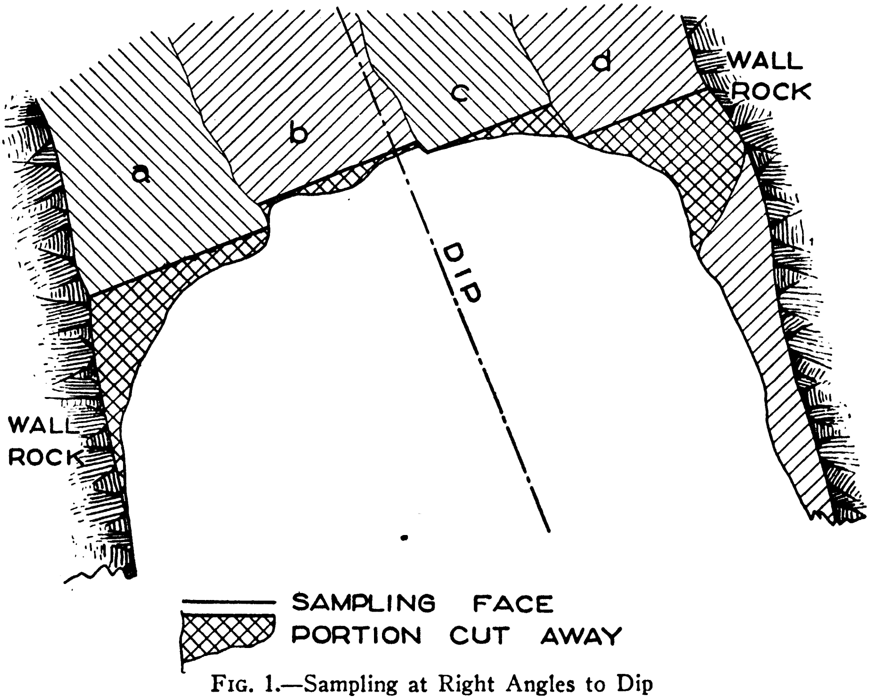

FIG. 1.—Sampling at Right Angles to Dip
a, b, c, d = mineralogic bands in vein

Distances apart.—One cannot state in hard and fast terms the distance apart at which samples should be taken in vein deposits. It will depend on the nature of the deposit and the order of occurrence of values. If the deposit is of uniform nature and of fairly uniform width and value, the samples may be taken at considerable intervals, perhaps of ten or twenty feet. If the deposit is narrow, or if the values are unevenly distributed, it may be necessary to take the samples as close together as three feet, or to take two or three cuts

to form a single sample covering the vein for the normal distance adopted between samples. Most engineers try to take their samples about five feet apart.

Having decided, from his study of the mine, what this distance is to be, the engineer should measure off every morning the proper intervals for the sections that are to be sampled during the day. He should not measure off more than can be sampled during the day, because the marked spots might be tampered with if they are left too long unsampled. When these sections are marked off into equal distances, the groove should be cut close to the marks. This eliminates the human urge which seems to draw the cutter of a sample irresistibly in the direction of rich spots, unless he be limited specifically to the exact locus of his operations. Samples should be taken at even distances apart, or as nearly so as the nature of the workings permits; this makes the calculation of average values much easier than it would be if the intervals varied, and permits use of the law of averages, which is an important factor in all sampling operations, particularly on alluvial deposits.

Though close adherence to the foregoing precepts is desirable, the rough nature of many of the faces to be sampled and the nature of the lode and distribution of values in it often call for some elasticity in choice of action, and the procedure at each face must be left to the judgment of the engineer or his assistant in order to determine what will give the most representative sample of the area of lode to be covered. It is often the case that a single sample will not be sufficiently representative, and where the distribution of values is erratic, two or three may be necessary.

In many orebodies the values occur in bands or laminations parallel to the walls. In such cases, where the grooves cannot conveniently be straight on account of timbering, irregular face, the fact that the vein is not broken to the walls, or the like, the groove may be stepped slightly.

The essential need is that every inch across the vein be represented in the sample in proper proportion to width. If this rule is observed, a wide latitude of action is permissible.

Loss of pay streak.—In his careful study of the mine the engineer often is able to get a better idea of its geology than the ordinary manager may have. Sometimes he may see clearly how the pay streak was lost, a loss that often happens when the manager works on preconceived theories and fails to notice faulting or sharp turns in the vein at points where it is very narrow. What the engineer

learns is, of course, the property of his client, and he should not be too hasty in disclosing to the owners of the property the valuable information that he may have gained.

THE SAMPLING PROCESS

Underground sampling.—The taking of samples in the underground workings of a mine is, it may safely be said, the hardest physical task that any professional man is called upon to attempt. Frequently the samples must be taken from overhead while one is standing on an insecure temporary trestle or staging on the slippery floor of a level or stope. Patience, strength, perseverance, and ingenuity are taxed to the utmost, for the sampler is dealing with nothing less obdurate than solid rock. The physical demands of such work, when added to the ordinary discomforts of toiling underground, are a temptation to skimp the labor of sampling, and aching bones and muscles may counsel a less conscientious performance; but neither time nor effort should be stinted to obtain samples as representative as possible.

It is sometimes necessary to make a fairly smooth and clean face for sampling. Although the physical labor of making this new face may be delegated to miner helpers, they should work only under the direct scrutiny of the engineer. This procedure of clearing the face will have the advantage of removing old rock which may be covered with barren incrustations and dirt, and which, moreover, may have been "salted" by treatment with preparations that would give fraudulently high values.

Upon this surface the sampler cuts, as nearly as he can, a rectangular groove from one to two inches deep and from two to six inches wide, to yield a predetermined weight per foot of groove, running from one to ten pounds. Many engineers seem to think that a large hand sample gives greater accuracy. This is only true when it is taken with the same minute care as the smaller one, which is rarely the case. Large lumps not broken down correctly to give the same proportion of each inch *across* the vein are often allowed to remain in a large sample but not in a small one. As a rule, therefore, fairly small samples taken with extreme care are likely to be more accurate than large ones.

In hard rock, the nearest approach the sampler can make to the ideal shape of groove will be a U-shaped notch, with corners sloping rather than square. This groove must be cut with a hammer and moil, a little at a time. When sampling is being done at well-

equipped mines a small air-driven hammer-drill may be available. Such aids have been rare in years past, but with the development of the use of air drills, gasoline engines, and small compressors, much of the hard work of the examination of unequipped mines may now be eliminated.[3] In large deposits much information may be obtained from the use of the diamond drill, but the examination and interpretation of the cores requires a high degree of skill and experience. Cases have been known in which the drill has passed completely through a vein and yet those in charge of the work did not detect this fact.

There are various devices for catching the material as it falls before the hammer and moil. Some men use a hat, some use a candle box, and some pick it up off the floor, upon which has been spread a canvas sheet. The ore bucket described by Herzig[4] is to be recommended. Care must be taken, of course, to make sure that material that may break loose from the face adjacent to the groove is eliminated from the sample.

A very common source of annoyance is that at times the moil breaks out a piece very much wider or deeper than the groove. Under these conditions it requires a high degree of moral courage to sit down on the floor of the tunnel and reduce this unwarranted excess to the proper dimensions. If the large lump is to be used at all, it is essential to break off pieces for the sample on the face of the lump at right angles to the lode. If broken off parallel to laminations, the sample is spoiled. Some very faulty sampling is done in this way, even by otherwise careful men. But the sampler should remember that a sample improperly taken is worse than none at all. If a large piece of hard ore has fallen into his sample, it may be easier to cut anew the section it came from rather than try to correct the error.

It may take a whole day, or even more, to secure one good sample, of from ten to twenty-five pounds, but under favorable conditions, when the rock was fairly soft and accessible, one crew has taken ten or more thoroughly satisfactory samples in one day,[5] and this figure may be much exceeded in narrow lodes or on easy ground.

If the engineer cannot cut his own sample, the next best thing is for him to hold the sampling bucket; but even then, if he fails to exercise careful supervision, the sample may be salted.

[3] See Eggers, John H., "Application of Air Drills to Mine Sampling," *Engin. Min. Jour.*, Aug. 30, 1919, pp. 358–60.

[4] Herzig, C. S., *Mine Sampling and Valuing*, p. 58.

[5] Hoover, H. C., *Principles of Mining*, p. 56.

Some readers may wonder why experienced, muscular miners are not employed to do this physically exacting work of cutting samples. The chief reason is that the miner working for wages has no technical responsibility or financial interest in accurate results of a valuation. He might, under the engineer's eye, perform the operation satisfactorily, but the moment he was free from observation, he might fill up the bag in the easiest way possible. In the course of a large examination, the honesty of a crew of miners trained on the spot must necessarily be relied upon to some extent; but the engineer must continually satisfy himself that the sampling is being done properly. In order to be sure of this, he should himself take a number of check samples. These check samples are taken by sampling alongside the grooves already made by the sampling crew. Such personal checking by the engineer should encourage the sampling crews to a high standard of performance.

Errors in sampling.—Errors in hand sampling may arise from any of the following causes:

1. Intentional salting for purposes of fraud. This is dealt with in detail in the next chapter.

2. Friable streaks in the ore, causing an excess of one such portion to enter the sample.

3. Hard streaks in the ore, causing a deficiency of one such portion to enter the sample. This is the converse of the situation given above. If the friable portion in the above case was comparatively rich, the assay would indicate too high a value for the whole. If the hard portion in the present case was comparatively rich, the assay would indicate too low a value for the whole. The way out of this difficulty is to sample the friable and hard portions separately, even though they are quite narrow, even less than an inch in width in certain cases where rich streaks occur. This calls for very careful measurement, and also the allowance, in calculations, for possible variations in specific gravity of hard and soft portions.

4. Failure to recognize ore, thus leaving it unsampled. The classic example is the zinc carbonate deposits of Leadville.[6]

5. Laziness and fatigue. The influence of these has been mentioned above in describing the actual cutting of samples.

6. Ignorance and inexperience. This can usually be corrected by instruction from the experienced engineer.

[6] Editorial Correspondence, "The Zinc Carbonate Discoveries in Leadville," *Min. World,* Dec. 17, 1910, pp. 1147–48, 1181.

7. Failure to see and examine all openings. Blocked-up sections may contain low-grade ore, although they have been known to contain bonanzas. This will be dealt with in the next chapter, under "Prevention of Fraud."

8. Failure to take samples at right angles to the vein; or, in lieu thereof, to make the necessary mathematical correction advised above in the section on "Width sampled."

9. Undue haste. A bad sample is worse than no sample.

10. Contamination of low-grade samples by material from high-grade samples adhering to tools, utensils, canvas, or machinery. The antidote for this is invariable and scrupulous cleanliness.

11. Failure to include seemingly barren spots in the sample scheme. These must be sampled separately or else recorded and excluded from later ore estimates.

12. Inability later to mine to the exact limits of the sampled block. This must be taken into consideration in the calculations.

13. Failure to include, in samples or calculations, weak ground adjoining the walls of the lode, which will be broken with the ore in stoping operations.

14. Failure to clean sampling surface. Clean thoroughly, even to the extent of blasting a new face where necessary.

15. Improper reduction to assay pulp of samples taken in the mine, or incorrect assaying.

16. False assumption that samples for irregularly spaced levels represent the average of each block. Such levels sometimes have followed the best ore, and the reasons for the irregular spacing call for investigation.

17. Confusion of samples. If critical samples cannot be allocated, unending trouble will follow. The remedy is painstaking recording and marking of all samples.

"Grab samples."—The theory of "grab sampling" is based on the assumption that the mineral is consistently distributed through the ore, and that if a few pieces of broken rock are selected haphazard from a heap, an assay of these pieces will be a useful guide to the value of the whole pile. Grab samples are occasionally used to obtain a rough valuation of ore dumps. Also, in the course of the ordinary operation of a mine the foreman continually employs the grab sample to check the grade of the ore, and sometimes the average of a large number of such grab samples, taken in the daily work of ore extraction, agrees remarkably well with the average obtained by milling. At the Mount Diablo mine, Candelaria, Nevada, the average of some

3,000 tons of ore was estimated at about $70 by the daily grab sample, and the mill sample agreed within a dollar of this estimate.

Beware of taking samples with a hand pick or a hammer. Accurate sampling for valuation purposes cannot be done with these tools except where the ore is extremely soft, as in certain oxidized zones, or alluvial.

Drill sampling.—The sampling of gravel deposits, or extensive low-grade ore deposits, is almost always accomplished by the use of hand or power machine drills; and the sources of error in this form of sampling are therefore different from those in the hand sampling of ore in place. Engineers who have performed the work of sampling gravel deposits do not agree on any standard practice to eliminate all possible errors. The subject has given rise to much controversy, which cannot be summarized here.[7] Sampling of gravel which is not too stony or deep is done by means of hand drills of the Empire or Banka type. For stony or deep ground the Keystone type power drill is the standard machine. All these machines drill a hole in the ground and remove the contents for examination.

The large porphyry copper mines were sampled by churn drilling. This was probably the most extensive sampling ever undertaken. The number of holes drilled up to 1910, according to Peele,[8] varied from 19,200 on 43 acres at the Miami mine up to 90,000 on the 105 acres at the Ray. The depth of the holes was from 200 to 970 feet.[9]

The method of diamond drilling is seldom used in mine sampling for the purposes of valuation, especially when the time of the option to purchase is short. When time is adequate the diamond drill may be a useful tool for the determination of values and extensions with depth. It also has a proper and useful place in exploration and the planning of development work in the normal routine of a mine's operation. A diamond drill yields a cylindrical core of rock, usually from ¾ inch to 1½ inches in diameter. In rocks of a reasonable degree of strength it will give an ideal sample. Expense precludes the use of this type of drill in the early periods of development of most mines.

Sampling of dumps.—Valuation of mines frequently involves the determination of the metallic content and tonnage of the mine

[7] See bibliography at end of chapter.

[8] Peele, Robert, *Mining Engineers' Handbook*, 2d ed., pp. 430–33.

[9] Rice, E. R., "Churn Drilling of Disseminated Copper Deposits," *Engin. Min. Jour.*, June 25, 1921, *et seq.*

dumps. These are not easy to sample accurately, as they are often composed of both ore and waste of varied size, exactly as this material comes from the workings. Blocks of ore weighing as much as a hundred pounds will be mixed with varying sizes of material down to fine dust. The dump samples, therefore, must be large enough to counterbalance to some extent the potential errors due to the presence of large pieces of low-grade material in a mass of relatively high-grade material. Miners have been known to hide large pieces of specimen ore in cars of waste which they tip over on a dump, intending to come in the night and carry these pieces away. Sometimes they cannot find their "high-grade," and it is covered up, later coming to light, perhaps, in an engineer's sample of a dump that has been represented by the owner to be low-grade milling ore. A small piece of such high-grade material will vitiate a painfully taken dump sample.

The shape of a typical mine dump suggests the proper method of sampling and measuring it (see Fig. 2, p. 60). If it is large, a survey must be made to determine its volume, and due regard must be given to the original formation of the ground surface before the dumping began; this requires the inspection of a reliable contour-map. If the dump is very large, the engineer may be at a loss to determine whether or not there may have been great irregularities in the ground which would materially affect the estimation of tonnage. However, since sampling will be accomplished by sinking shafts in the dump, as well as by cutting trenches across it, the bottoms of such shafts will eventually reach the original ground surface and thus points may be found to indicate the form of the original underlying surface.

If shafts are sunk for sampling purposes they do not need to be large. A dimension of 32 inches by 38 inches is generally sufficient —indeed, when the work has been done by small men, shafts have been made as small as 22 inches by 28 inches. If the dump contains large rocks the shaft must of course be bigger. These shafts must usually be timbered or otherwise supported for their entire depth, not only because the dump material is loose and therefore unsupported holes are dangerous, but also because an accurate sample of material, usually dumped in horizontal or slanting layers, cannot be obtained unless the shaft is kept of uniform size for its entire depth—or at least the depth covered by each sample, if the shaft is sampled in sections. It is often desirable to sample by sections, since some dumps contain layers consisting merely of waste rock from shafts or crosscuts or barren sections of the lode. The best way to support

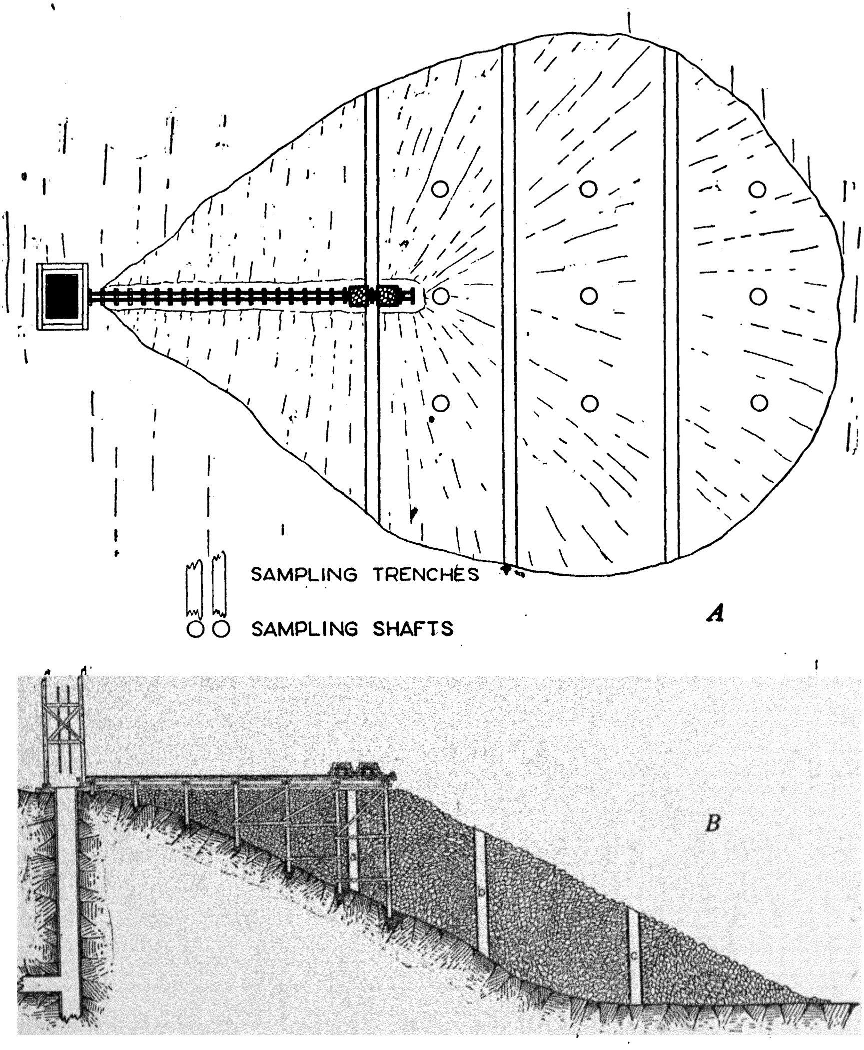

FIG. 2.—Sampling of Dump. *A,* view showing placement of sampling trenches or sampling shafts. Only one of these two methods would be used. *B,* cross-section of dump showing shafts or trenches to ground level (*a, b, c* = sampling trenches or shafts).

a shaft driven through loose material is to use elliptical rings of ⅜-inch by ½-inch bar iron supporting driving boards, which may be strips of corrugated iron eight to twelve inches wide and not more than five feet long. The rings are supported during the progress of the work by hooks, about five feet in length. Some of the hooks

should be provided with turnbuckles in case the original hooks are broken during the work and need to be replaced.

The excavation of such a shaft may give a sample of many tons. This quantity must be broken up and quartered down, with or without preliminary sorting out of waste rock, and progressively reduced by crushing to a size suitable for assaying.

Trenches also may require timbering if they attain a depth of more than a few feet. Wide trenches are to be avoided, as they yield samples of many tons, which are therefore expensive to handle.

The volume of the dump should be determined by such methods as its slope suggests. Sometimes the prismoidal formula (see Peele's *Handbook*, p. 1726) will be useful. The cubic feet per ton of material will be ascertained by dividing the cubic contents of the shafts by the weight, after deducting moisture content, of the material taken out of them.

The latest development in the sampling of dumps is the utilization of the power shovel. If the enterprise involved is one in which an accurate figure for this factor is of vital importance to the valuation and finance of the enterprise, this method solves a dilemma which many engineers have faced. Anaconda engineers a few years ago sampled a waste dump at the Badger mine, took out a 40,000-ton sample with a shovel, and got an average value of 0.98 per cent copper. The entire dump of approximately a million tons was then shipped to the smelter and yielded 0.96 per cent copper.

TREATMENT OF SAMPLES

Identification.—The correct and accurate marking of samples is of extreme importance, and in no other part of his work does the examining engineer so reveal his caliber as in the care of samples taken under his direction. No more useless object exists than an unidentifiable bag of rocks, apparently of so little worth that nobody troubled to give it a name. Since each sample has cost both pains and money, it should be marked in such a way that its identity will survive the many vicissitudes of its career.

Upon a fairly large piece of strong paper should be written the serial number of the sample. This should be folded into small compass and placed in the top of the bag, where it will keep drier if the ore is wet. A large sheet of paper thus folded has the advantage of protecting itself against losing its legibility. Many engineers recommend that the number of the sample should be painted or writ-

ten with indelible pencil on the outside of the bag, in figures two or three inches high; or that a shipping tag should be attached giving number and other information. Such a method is to be condemned, for although it allows the selection of a particular sample from the heap without opening every bag, it is a temptation to interested persons outside the party to gain knowledge that might be misused. However, some code system of lettered bags corresponding to serial numbers could be employed for ready selection of a desired sample, with greater safety.

When the record sheet and the sample are placed in the bag, the neck should be tied tightly with durable string and sealed with wax. Observations upon the sample should be recorded in notebooks immediately, so that delay will not cause details to be blurred or lost from mind.

There are almost as many methods of numbering samples as there are engineers. The best and simplest plan is to number the samples serially in the order in which they are cut. If more than one man is cutting, each should use this system, further distinguishing the serial number by placing his initial after it. The notes and sketches in the field book will show how many samples comprise the full width of the vein, and will also show the location by measurement from some fixed point, such as the intersection of drives and crosscuts, or the distance from a shaft, a raise or winze, or from a fixed and numbered survey station. Such information should be carefully recorded on the spot, in as much detail as will later be necessary to identify the sample.

Preparing samples for assaying.—Samples as they come from the mine may be wet and muddy, and will also consist of pieces of uneven size. Before the assayer can begin his work the ore must be dried and reduced to suitable size.

Under ideal conditions, each day's samples should be assayed the following day. If the examination is done by a small party, this may involve taking samples on alternate days. Frequent assaying not only limits the possibilities of salting, but also allows any abnormally high- or low-value spots to be checked by immediate resampling.

If an isolated prospect or other small mine is examined far from assaying equipment, the samples will necessarily be taken to civilization before anything further can be done with them. In such a case extra precautions should be taken, for the engineer will not be able to return to the site for resampling or confirming results.

However, any mine of appreciable size will certainly possess an assay outfit and place it at the engineer's disposal, which will probably enable him to make daily assays of samples.

It may be worth mentioning that the engineer, when confronted with the task of drying out the ore, may use in the absence of a proper drying oven a piece of sheet iron set on bricks or stones. Care should be taken not to roast the ore during drying, thus vitiating the results. A few bread pans will be useful in this operation. Ores containing large amounts of clay may take some time to dry.

The dry samples should be crushed to such size as the engineer considers will give, in the sample retained for assay, a true representation of the original sample. This will depend upon the size of the original sample and also on the size of the quarters drawn from it, and also on the uniformity in distribution of values; the size will ordinarily range from 20- to 40-mesh; but 100- to 150-mesh is much better. The crushing and quartering down can be done in one stage or in several, depending on the size of the samples and local conditions. One may use the crushing machine found in modern assay offices, or a small hand crusher, or a mortar and pestle, or even simply a hammer with a large rock as anvil. If a mortar and pestle must be used, swing the pestle on a spring-pole, sapling, or tree limb. If obliged to use the hammer and rock method, one may save much time by dividing the work among a number of men and providing each with some sort of anvil set upon a piece of canvas to catch the broken fragments.

Details of the methods for reducing the sample thus obtained to an assay pulp will be found in any standard book on assaying. Quartering the sample is simplified by mechanical devices such as the Jones sampler.[10] After the sample has been put through the sampler and a portion has been selected for assay, put the remainder of the sample into a bag, including with it the original record sheet or a clean number slip. The portion selected should be ground on a bucking board, if no better device is available, to a grain size that will pass through 40-mesh or finer, to meet the needs of the assayer.

[10] Herzig, C. S., *Mine Sampling and Valuing*, p. 26.

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Chapter 4

Sampling (Continued)

CHECKS ON SAMPLING

A single sampling is not a sufficient basis for the valuation of a deposit. The checking of results is as important in valuation surveys as it is in any other field of engineering endeavor. Hand sampling results may be checked by resampling at the same site, or when possible by mill runs, or by both.

Resampling.—A good method of checking is by partial resampling with changed crews. But even if the resample agrees with the original sample, there is no absolute surety that the true value of the ore will be shown by the assay results; for it is an often-observed fact that valuations of ore based upon hand sampling usually exceed the truth by from 5 to 20 per cent, even when the greatest care has been exercised in taking the samples. The percentage of error in sampling will vary for each mine and each examination of that mine, and should be determined in each case, if possible, by mill runs.

Mines have been classified by Webber,[1] for purposes of sampling, under five heads:

1. Mines where the average metal-value is mechanically reduced, but where the unaccounted metal may be subsequently recovered.
2. Mines where there exists an unrecoverable loss.
3. Mines where sampling indicates a fictitiously high value.
4. Mines where sampling results in an incorrect subnormal value, conclusive proof being afforded by subsequent commercial results.
5. Mines where sampling is of no use.

Whether the engineer should plan to resample 5 per cent or 40 per cent of the original number will depend on the type of mine, as listed above, and upon a study of the particular situation and the goal in mind. The calculation and tabulation of results, and the assay plan, must be scrutinized for abnormally high returns, and spots

[1] Webber, Morton, "Unavoidable Errors in Sampling," *Min. Sci. Press,* June 24, 1911, p. 846.

giving these high returns should all be resampled. A certain portion of the other grooves or cuts should also be resampled as a check on the accuracy of the work and as a precaution against fraud.

The resampling should, when possible, be conducted by a man or crew different from the one taking the original sample. If the resamples check within 10 per cent, the work will have attained a fairly high level of excellence. If the difference is greater than 10 per cent, doubts will arise, and the cause of any large discrepancy must be tracked down and corrected. For this reason, resampling should be begun as soon as original sampling is well under way.

Abnormally high values are often dealt with drastically. If resampling confirms original high values to a suspicious degree, the returns are cut down arbitrarily to the average—either to the average of the ore shoot being sampled on that level, or to that of the two adjoining samples. These averages, of course, should not include the assay value of the high sample itself unless it is confirmed by a check sample. This arbitrary procedure does not find its justification upon mathematical grounds, but arises from long experience that almost all extremely rich samples are too good to be true. There are, of course, types of ore deposits for which such drastic treatment would be neither necessary nor justifiable, and the application of this general rule must be left to the judgment and experience of the engineer.

If sampling returns are uniformly high, and the samples have been taken with proper accuracy, it must be assumed that the mine is a rich one, and that the ore when mined will have an equally high value. When the ore reserves of the Tomboy mine in Colorado were estimated, the richest assay returns were eliminated from the calculations, but the later results from milling operations revealed the accuracy of sampling by yielding values higher than estimated, making the precaution of reducing high sampling results an absurdity. This, however, was an exceptional case; estimates from sampling are in almost all cases higher than the recoverable values.

The proper appreciation and use of assay returns is a complex operation that requires experience and judgment. However, such difficulties as those encountered in all such operations in the process of valuation are indirectly of benefit to the mining engineer's profession. If the valuation of a mine were merely a task that could be reliably performed by any recent mining-school graduate, armed with a pick and a measuring tape, the years of experience behind the expert engineer would be of no worth to him.

Large-scale sampling.—The most accurate check on sampling is the mill test. This test must, however, be used with caution, as the chances for salting and possible confusion are greatly increased. Extreme care must be used in selecting the ore for testing to make it representative of the whole mine or the part under examination; and its treatment must be alertly watched. All chutes and passages for sample ore in the mill should be made spill-proof. Mill equipment, such as grinders, ball mills, classifiers, bins, etc., should be cleaned before and after each test run, to make sure that fine high-grade material lodged in the machines does not pass into the sample following.

Mill-test results are often the basis of payment when ore is sold, and custom "sampling works" make it their chief business to perform such large-scale sampling.

The advantages of large-scale sampling of ore deposits by fractional selection from carload lots and mill runs are often overrated by amateurs. If the carload lots and mill runs are to be considered as accurate guides to the value of the deposit, they must be selected on the same principles that govern the cutting of a groove across the vein, and with the same regard for mineralogical occurrence and other factors. Since such samples are large, they are apt to be extremely expensive and to take much time, and if no gain in accuracy is made, little can be said in favor of the large-scale method as a sole means of determining ore values. Combined with hand sampling, however, it sometimes forms a useful adjunct to the valuation process. If facilities exist for large-scale sampling by smelter or mill runs, and time and money permit, such runs—or records of previous runs—will serve a useful purpose when accompanied by a close study of development work and stoping plans.

The method of combining hand sampling and mill tests has been elaborated by Morton Webber.[2] Most of the engineers who have participated in the voluminous discussion of Webber's method are convinced of its utility. The essence of the method consists in determining the percentage of error for values given by hand sampling by running bulk samples through a mill or sampling plant. The method is especially advisable in the valuation of large low-grade gold orebodies. An extraordinary example of the failure of the ordinary valuation methods for this type of deposit was seen in the operations of an Alaskan mine, where a loss of many millions

[2] Webber, Morton, "The Combination Method of Mine Sampling," *Min. Sci. Press*, Feb. 28, 1920, pp. 303–306.

resulted from improper sampling. A prominent engineer who was among the losers has stated that he believes the loss might have been avoided had the "combination" method been used.

Mill tests will be further dealt with later in this chapter, under the subheading of "Metallurgical Study."

RESULTS OF SAMPLING

Assay returns.—No warning should be needed that assaying of samples should be performed accurately and carefully, with due regard to the possibility of contamination of the fluxes. This work should preferably be placed in charge of an experienced assistant. If the size of the job warrants the employment of a reliable assayer, the whole task of drying, crushing, and quartering the samples can be given over to his care, leaving the chief engineer and his other assistants free to pursue the underground work every day.

Local assayers should be viewed with distrust, since many of them have interests in the neighborhood prejudicial to accurate returns from sampling. If samples are to be shipped to a custom assayer, they should first be ground to insure that this important work is properly done. The engineer should always keep a duplicate set of samples, and instruct the assayer to preserve the pulp in case a re-assay is required. The possibility of salting at the time assaying is performed is discussed later in this chapter. Assay returns should be entered on the assay plan as soon as they are obtained.

The engineer may often derive considerable knowledge by a careful microscopic study of the ore and by panning tests. Familiarity with the ore in an individual gold mine often enables an experienced engineer to make a close approximation of its value by panning tests; the percentage of mercury in an ore containing cinnabar may also be closely estimated by panning, and the same method will give a helpful result on sulphide ores. In the examination of gold placers, a graduated series of small glass tubes containing weighed amounts of gold equal to various monetary values will be useful in estimating value per volume (cubic yard, meter, or sagene) of material panned.

Specific gravity determination.—There remains one other important factor in the calculation of ore values which must be explained; that is, the determination of the specific gravity of the ore. This factor does not enter into the early calculations, but it will be found exceedingly important at a later stage, and the figures must be prepared while the underground work is going on.

When the sample is given to the assayer he puts it through certain well-known operations; and later he reports that this sample contains a certain percentage or weight of metal per ton. Not only must the engineer thus discover how much metal there is per ton but also how many tons of that ore there are in the mine. Not all the ore in the mine can be put on the scales and weighed; so linear measurements must be used to determine the volume, and these volume measurements must be transformed into weight. From linear measurements, the number of cubic feet of ore there may be in the entire mine or in the separate blocks of ore can be calculated. Hence it is important to ascertain the number of cubic feet of this ore it takes to make one ton.

The textbooks give numerous tables of specific gravity and the number of cubic feet of each mineral that will make a ton. But ores are usually mixtures of minerals; therefore, at times the determination of the relation between volume and weight becomes a complicated problem. For this reason it is necessary to take into account the effect of any large error in the determination of specific gravity.

Assume, as a simple instance, that a gold mine where the ore is practically pure quartz is being examined. The specific gravity of pure quartz is 2.6; or, in other words, it requires about 12.3 cubic feet to make one ton. Most veins contain cavities and small vugs for which some allowance must be made. An allowance of fourteen cubic feet to the ton of ore to make up for these cavities might on occasion be liberal. Suppose this allowance proved too liberal, and that instead of taking fourteen cubic feet to make a ton it takes in reality only thirteen cubic feet. The error in this case would be about 7 per cent, which would mean that the tonnage as calculated would be 7 per cent less than the true tonnage.

This error may seem large, but it probably would not vitiate the final conclusion upon the value of the mine, for if a mining business had to be purchased upon such a narrow margin of value that 7 per cent error in the tonnage of ore would make any vital difference, the property would justly be condemned as a dangerous investment. However, the duty of the engineer is to avoid errors in his examination, no matter how much or how little they affect the general result; so that every effort should be made to get an accurate figure for the specific gravity of the ore. This figure may be determined by four different methods:

1. If mining operations are going on, the first method may be

employed. This will consist of mining two or three carloads of ore at several faces, accurately measuring the openings thereby created, and weighing the ore.

2. The specific gravity of large lumps of typical ore (which may vary greatly in different parts of the mine) may be determined by weighing in water and air. The size of the lumps will depend on the available scales and apparatus.

3. The specific gravity may be determined by ordinary laboratory methods, with the specific gravity bottle, using small fragments of ore, as free from slime as possible.

4. As a check, the specific gravity of the ore may be determined by calculation from the known specific gravity of its component minerals. This last method depends on having an analysis of the ore in sufficient detail to enable the listing by volume, to a fair degree of accuracy, its mineralogical components.

Moisture content.—The specific gravity determinations should be made on the dry ore or an allowance should be made for moisture, for the assayer's returns are based on dry ore. In mines where the ore is hard, this allowance for moisture is not important, but if the ore is soft or oxidized, it may carry as much as 20 per cent of water, and neglecting to allow for this would make a decided difference in estimates of tonnage and value of the ore reserves.

The amount of moisture in the ore as it comes from the mine may therefore be a considerable factor in its valuation. Not only does the cost of transporting water through the various stages of ore-handling cut into profits, but also, since the ore must be dried out in many reduction processes, the amount of fuel consumed will be increased.

Metallurgical study.—As the examination proceeds, the problems involved in the metallurgical treatment of the ore must be studied. The mine cannot be properly valued nor can the ore reserves be estimated until the form of metallurgical treatment is selected.

At a developed and operating mine, this metallurgical study will consist of a careful analysis of all past records of the treatment plant, and of sales reports; it will also involve careful sampling of the tailing heaps, and a study of the daily operations of the plant over as extended a period as the terms of the option will allow. The manager of the mine, on behalf of the owner, will have made certain representations concerning the tonnage treated, its value, the percentage of recovery of the metal, ratio of concentration, costs of

treatment, and profits; it is the engineer's business to check these figures and prove or disprove the statements made.

Two formulas[3] may be used in the study of metallurgical mill or smelter data. When these are applied to the assays of the ore, product, and tailing, as given by the manager, hardly ever do they give a percentage of recovery equal to that claimed by him.

Let

$$a = \text{assay of ore}$$
$$b = \text{assay of tailing}$$
$$c = \text{assay of concentrates.}$$

Then

$$\text{percentage of recovery} = \frac{100\,c\,(a - b)}{a(c - b)}$$

and

$$\text{ratio of concentration} = \frac{c - b}{a - b}$$

These formulas are independent of tonnage.

The manager's opportunities to make errors in calculating the percentage are very great, and may occur through mistakes in weighing, sampling, assaying, and determining moisture content—alike of the ore, product, or tailing—or through unknown losses of some of the material handled. Moreover, each operation is open to the hazard of error in computation. These sources of error, which may occur singly or in combination, are pits into some of which the engineer himself may easily fall while trying to find out which of them the mine staff is occupying.

The normal errors of scientific measurement will of course exist in all of the operations cited, but these are not large, and many of them tend to cancel each other. Furthermore, a careful scrutiny of each operation will convince one that the maximum possible error, in the absence of fraud, will not affect the result to such a degree as to cause great uneasiness. If the staff of the mine approaches the standard of modern efficiency, the greatest chances for error that will materially affect the result will lie in those operations having to do with weighing the ore, determining moisture content, and taking samples. If application of the above formula for percentage of recovery reveals a discrepancy greater than one per cent when the

[3] Hoover, T. J., "Calculation of Recovery in Concentration," *Engin. Min. Jour.*, June 11, 1910, pp. 1234–35.

manager's figures are used, a systematic search should be made for the cause, which will more probably lie in the methods used than in any attempt to defraud.

The same care should be observed when taking samples in the course of the metallurgical study as was observed when mine samples were taken. Automatic samplers may be installed at important points, and certain periods of the mill operations should be set aside for special runs on ore hand-sampled for valuation purposes, as a check on such hand sampling and a means of establishing the factor of error in the method of sampling employed. When small mines unequipped with treatment plants are examined, these mill tests, if made, must be made elsewhere, either at some mill where suitable metallurgical treatment obtains, or at a custom smelter, testing works, or sampling works. In all events, as has been stated previously, the mill test, when practicable, is one of the foundations of evaluation, confirming and being confirmed by the results of hand sampling.

If the mine under examination is without a metallurgical plant, the mill test elsewhere has the further function of enabling the determination of the proper form of metallurgical treatment. Even if a plant is in operation, some improvement in method may be discovered, or some new method suggested by operations on similar ore elsewhere, which will pay an additional profit. Theories for increasing the efficiency of a plant should be supported by further investigation, on the ground or elsewhere, before any radical change is made. However, the engineer should be warned in his valuation work not to hope for any great increase in efficiency of metallurgical treatment through the installation of newly invented or untried processes. If the business will not justify the investment of capital when using standard and proved metallurgical methods, the risk is increased rather than decreased by contemplating greater profits through the use of new inventions of unproved worth.

CALCULATIONS FROM SAMPLING

The office work that will be carried on, as daily reports of sampling, assaying, and other evaluation operations are coming in, may be performed in such a manner as to be the dullest drudgery, or it may be made a source of pleasure and confidence. In order to make it a pleasure one thing is needful: to keep it up to date every day.

An ideal (though rarely possible) arrangement is to have available for this work a large room which can also be used by the ex-

amining staff as a dining-room and by some member of that staff as a bedroom. Here should be kept under lock and key, when not in actual use, the samples, the field books, the calculations book, and all the maps and records of the examining crew; and it should be the rule that during the whole period of the examination this room is never to be unoccupied by a member of the examining staff, and that representatives of the mine owner must never enter it.

Every night without fail all the information, including assay returns, that has been secured during the day should be entered in the calculations book and on the maps and plans. No eight-hour day will suffice for the conscientious examining staff. A mine examination cannot be satisfactorily carried on unless all facts are recorded daily, discussed with assistants, and used as basic facts from which deductions are drawn as guides to further research. This daily discussion will include the subjects of geology, mineralogy, metallurgy, values of samples, prices of metals, and all other points that have come within the purview of the chief and his assistants. Such discussion enables the immediate resampling of locations where abnormally high assay values are secured or where suspicion arises as to the validity of the samples.

The calculations book, then, must be kept systematically and accurately. It should be ruled off to suit the particular nature of the mine and the number of metals contained in the ore. The arrangement should be such that there is sufficient room for a record of all samples from each level, raise, or winze to be kept together in consecutive order. It is not necessary, however, to enter all the information from the underground notebooks in the calculations book, because some of this information will form the basis of the maps.

If a groove has been divided into several samples, the caluculation of the average value of the groove should be made with due consideration for the method of mining that will be necessary in the vicinity of that groove. If, for example, a hard, high-grade streak of ore occurs along a soft wall, a suitable volume of wall rock, as indicated by the examination and sketch of the sampler, should be allowed for in the calculations.

If the different sections of the lode sampled have sufficiently different specific gravities—for example, if one is galena and another quartz—this must be allowed for in the calculations, because a width of galena would yield a much greater weight of ore than an equal width of quartz.

The reason why accurate determination of the true width of the

vein has been so highly stressed previously is because width of vein is used in the calculations rather than the number of tons of ore in the mine; it is assumed that the tonnage is proportionate to this width of vein. To determine the average value of the ore for each groove, or the average for the level or the block, the assay value is multiplied by the width in inches or in feet. Engineers prefer to use feet and tenths of a foot, and their tapes and rules are laid off to that scale. Multiplication of width by assay value gives an arbitrary figure called the foot-dollar, or foot-percentum, or inch-shilling, or any other standard combination. The sum of these foot-dollars, or foot-percentages, for the samples to be averaged, divided by the sum of all the widths sampled, gives the average assay value of that cut or section. Calculations should be made in dollars when dealing with gold, in ounces when dealing with silver, and in percentages when dealing with other metals. Values should not be given in dollars per ton until the final average for a block or section is found, at which time the assumed market price of the particular metal should be used to obtain value per ton.

It is assumed that the mine is composed of "blocks" of ore—some blocks developed on four sides, others developed on three sides, and others on two sides, and some of odd and inconvenient shapes. This concept will be discussed and applied in chapter 6, on ore reserves.

THE PREVENTION OF FRAUD: "SALTING"

One of the greatest troubles of the mine-valuing engineer is the guarding of his samples against salting, or fraudulent enrichment of low-grade samples by the addition of extraneous high-grade ore or metal in some form. Salting is a practice resorted to by dishonest vendors or their agents, aiming to raise sampling returns to a spuriously high figure; and many good engineers have fallen victims to the tricks of the salter and have thereby made favorable reports on worthless mines. However, of late years the devices of the salter have become better known, and the engineer has learned many ways of protecting himself. He should use some form of safeguard at every step, and never assume that any sampling situation is free from attempts at salting. The trick is an old one, and until human nature changes more than it has in the last few hundred years, attempts at salting a mine will not soon disappear; in fact, in recent years there seems to be an increase in the number of these attempts to defraud.

The literature of mining contains many descriptions of the ingenious schemes attempting to introduce misleading values into samples or otherwise to heighten the apparent worth of a mine at the time of valuation. The following incidents reveal some of the methods of salting that have been employed:

A man in Shasta County, California, stated that he had an excellent copper mine for sale. The engineer who sampled it found that, although it was a poor copper mine, the ore assayed a high content of gold. He bought the property on the basis of its apparent gold value, and then found that the owner had salted the workings with gold, using a shotgun. The engineer had no redress because the owner had made no representations about gold content.

A mine was offered for sale on the basis of a month's mill run, to be conducted by the prospective purchaser. Ten thousand tons of rock were put through the mill and yielded a very excellent result, which the seller assured by feeding about $20,000 worth of gold amalgam into the ore in some unknown manner. As he sold the property for ten times that amount, his outlay of $20,000, though reprehensible, was profitable to him if not to his victim.

In the early days of the Comstock Lode, a mine was sold on the strength of sampling returns from the bottom of the shaft. This spot was filled with loose rock from previous blasting, which was sampled by an engineer who did not take the trouble to clear it out and cut samples from the unbroken floor. The sellers had placed in this loose rock certain substances that assured a high assay, among them a badly battered silver half dollar, which was later found by the new owner when he cleaned out the shaft.

Some methods of salting.—The following are some of the commonest types of salting. In the next section of this chapter a list of safeguards against each of these methods is given.

1. *Salting of ore in mine.* Before the engineer comes to sample a location, metal values, or "salt," may be applied on or injected into the rock. This may be done by loading a shotgun with such substances as gold dust, silver filings, rich argentiferous minerals, or some other material by which the miscreant hopes to raise the apparent value of his ore, and firing it into the face to be sampled. These substances do not penetrate into the ore but enough will adhere to the surface to vitiate the result. Also, rich solutions of gold chloride, gold cyanide, or silver nitrate, painted on the faces of the openings, will dry in place, if the face is dry, and thus salt the surface to be sampled. If the faces are wet, this painting process is not

effective. (For methods of protection, see safeguards D, E, F, G, and H, below.)

2. *Introducing values into the sample while it is being taken.* This is an easy matter when sampling is left to others than the engineer or his trusted assistants. Even in the presence of the engineer or his assistants, however, fraudulent values may be introduced by a number of methods, such as gold in cigarette ashes, small balls of clay containing gold which may be thrown surreptitiously into the sacks, or even by spitting gold dust into the sample. Gold amalgam carried under the finger-nails of a miner, or pellets the size of homeopathic pills, can be introduced into a sample under the eyes of trusted assistants with small chance of detection on the spot. In one case, the whole bundle of new canvas bags which the engineer had bought to contain his samples were contaminated with a pinch of gold precipitate placed in the selvage inside each sack. (See safeguards A, B, C, E, F, G, and H.)

3. *Introducing values into sample sacks after they have been tied and sealed.*[4] This may be done by injecting solutions containing gold, silver, or copper into the sacks with a syringe; or, if the engineer leaves his sample unguarded, it may be done by ripping the bottom seam of the sack, introducing "salt," and sewing it up again. This has been done in the express office with the connivance of a dishonest express employee. At a mine in West Australia, sealed bags were punctured and a quill inserted, through which gold panned from the same ore was blown into the sample. (See safeguards B, C, E, F, G, and H.)

4. *Introducing values into the sample during crushing, mixing, and quartering.* It is often necessary to have this work done by ordinary workmen, and even under careful supervision the methods described in (2) above may be applied at this stage. (See safeguards B, C, F, G, and H.)

5. *Introducing values into the fluxes used in assaying.* Even if an honest assayer is employed, a dishonest seller may be able to contaminate the fluxes. A case is known in which the crucibles of the assayer had all been treated with silver nitrate and then carefully dried at a red heat. (See safeguards C, E, F, G, and H.)

6. *Fraudulent report by assayer.* This should not occur if a trustworthy assayer or a reputable firm does the work. If, how-

[4] McDermott, Walter, "Mine Reports and Mine Salting," *Trans. Inst. Min. & Met.*, London, Vol. 3 (1894–95), pp. 108–49.

ever, an employee of the seller or a dishonest assayer assayed the samples, this source of fraud should be eliminated by applying safeguards B, C, E, F, and H.

In the early days of mining on the Pacific Coast, assayers who returned high values from all samples brought to them were not uncommon. One of this type was very secretive, and allowed no one to enter his tent. Eventually, suspicious clients discovered that he had neither furnace nor balances, but used an ordinary stove in which he made a fire in order that the escaping smoke from his stovepipe might suggest that he was working at his craft.

Fraudulent assayers are still in existence. In 1920 a doctor living in San Diego induced capitalists to investigate certain deposits which he understood were extremely rich. During an investigation lasting several months, the engineer traced the previous high assays on ores from these deposits to one firm of assayers, but in no case did his own sampling and assaying reveal any ore worth developing. Presumably, these assayers acted on the theory that by consistently reporting high values, prospectors would be encouraged to bring them further business. At any rate, the engineer's faith in the firm was destroyed when they returned to him a report of $15 per ton from the fragments of a grindstone. (See safeguard C.)

7. *Fraudulent values introduced into mill tests or shipping tests.* One such case is described above. Not only may values be introduced into ore milled or shipped, but sometimes into concentrates. (See safeguards A, B, C, E, F, and I.)

8. *"Innocent" salting during assaying.* Although this is not a fraudulent practice, it should be mentioned in this place. "Innocent" salting occurs when an honest but careless assayer uses a crucible in which rich ores have been melted, thus salting a poor ore. The remedy for this is to use new crucibles. Particles of rich ore may also remain in the sieves, mortars, or on bucking boards if they are not properly cleaned between runs.

At the Northern Belle mill, in Nevada, this source of error caused much annoyance and was with great difficulty detected and removed. Recently an unfortunate promoter was painfully misled by reports of platinum in a wide vein of low-grade gold ore that had been assayed in an office where platinum was frequently melted; it was only after much investigation that the fluxes were found to contain platinum. Such a condition could be discovered by running "dummy" assays (see safeguard C). It should be borne in mind, however, that even correct assays may be misleading, as is clearly

shown by Professor Charles E. Locke[5] in his discussion of the working of Nova Scotia gold ores.

Amalgamation tests are sometimes a source of error. Adirondack sands containing a value of ten cents per ton, by assay, ostensibly returned values from $5 to $30 per ton when amalgamation tests were used.[6] Subsequently gold was found in the quicksilver used in the tests. H. M. Chance, who reported this case, had a similar experience in Nevada when a prospector estimated $20 to $30 worth of gold per ton by amalgamation tests, although no gold could be found by panning. The quicksilver used had been purchased from a reputable firm, yet by examination it was found to contain fine gold.

9. *Preparing the mine for sale, or "dressing" the mine.*[7] This method is possible if the rock is of such a nature that one familiar with the general distribution of the values can distinguish with the eye which parts are barren. It is a method of fraud carried out by a representative of the seller, by systematically mining out all the low-grade or barren spots in the vein, leaving only the high-grade spots exposed. This method is used on deposits of lead, zinc, and copper, where the values are in the form of sulphides or other minerals distributed in a coarse and irregular manner in the vein. It may also be used in a gold or silver mine if the seller is familiar enough with the difference between high- and low-grade ore. In a mine dressed for sale, there is a lack of straight lines which is in itself suggestive. The back or top of a drive or stope will have a billowy appearance, which is the result of gouging out the low-grade places. (See safeguards D, E, and H.)

10. *Concealing the bottom of the mine and working faces.* There are certain critical portions of a mine that vendors have been known to conceal for fraudulent purposes. These are usually places at which evidence of decrease in values has been shown by development work, or where the vein has pinched out and the seller would attempt to convey the impression that there are possible rich extensions; on the other hand, there have been cases when the seller gave an option on his mine at a certain price, and subsequently discovered a great

[5] Locke, Charles E., "School Laboratory-Work: the Sampling of an Ore Containing Coarse Gold," *Trans. A. I. Min. E.*, Vol. 45 (1913), pp. 251–55.

[6] Chance, H. M., "Gold in the Adirondacks," *Engin. Min. Jour.*, April 2, 1910, p. 695.

[7] Editorial: "Dressing a Mine for Sale," *Engin. Min. Jour.*, Sept. 4, 1920, pp. 442–43.

FIG. 3.—Photomicrograph of Gold Filings Used to Salt Mine (×130)

Fraud was detected by microscopic examination of panning residues. Note marks of file and spiral form of metallic shavings. (Photograph by O. Cutler Shep-

bonanza which he tried to conceal so that the examining engineer would not find it. In the early days at Eureka, Nevada, a vein of rich ore was built for several feet in the end of a drift where the vein in the face had pinched to a small stringer. This deceived the buyers and the mine was purchased; on further working, the stringer widened out and developed into a good orebody, and the fortunate buyers made a large profit on their purchase.[8]

In another case a drift was packed solidly with waste to simulate the end of the mine, but the inquisitive engineer had this drift cleaned out and found hundreds of feet of workings where there was supposed to be virgin ground, and his discovery stopped a sale that otherwise might have been completed.[9] (See safeguards E and J.)

11. *Deception by fraudulent weights.* Cases are known where a wrong conclusion was derived from the use of scales the weights of which had been tampered with. All borrowed instruments should therefore be tested for accuracy.

There are other variations of salting and sources of error that do not appear above, but these are the most prominent types. It will be observed that the safeguard described under "E" below is the only one that will serve as protection against all methods of fraud, but even so it should not be solely relied upon.

Safeguards against salting.—Methods of detecting frauds of this sort are numerous, and only the principal ones are given below. Other safeguards will no doubt occur to the engineer as he gains experience.

A. *Care in sampling.* Adequate precautions at the time samples are taken furnish the best protection against salting by many methods. If the engineer is sure that the sample has not been tampered with, a check on subsequent attempts may be applied by first thoroughly mixing the sample and then dividing it into two unequal parts before putting into sacks; this makes it almost impossible for anyone to add the correct amount of "salt" to each portion so that both should give the same assay value. Precaution in taking samples, as well as notes and observations made at the time, should aid in the detection of salting methods (2), (5), and (7).

B. *Resampling.* Whether the mine examination be great or small, the engineer should return to his grooves, after the original sampling, and take a number of check samples, which should be

[8] Verbal information from W. H. Shockley.

[9] McDermott, Walter, "Mine Reports and Mine Salting," *Trans. Inst. Min. & Met.*, London, Vol. 3 (1894–95), p. 135.

secured with unusual precautions and guarded throughout their treatment. If this resampling can be done by the engineer unaided, the likelihood of salting by method (2) will tend to decrease. If fraudulent metal values are introduced during a mill test, as described in method (7), a complete set of duplicate samples would reveal the fraud. If the duplicate samples are taken by the examining engineer somewhat later than the original samples, the culprit must necessarily introduce his values into both samples, in like measure, before assaying, or the assay will expose him.

If the original sampling was done by necessity without perfect supervision, a key-series of shifted numbers offers considerable protection against fraud by methods (2), (3), (4), (6), and (7). Suppose samples numbered 10, 11, and 12 of the original series are to be resampled. The resamples should not be numbered 10*a*, 11*a*, and 12*a*, but should be given numbers quite different, so that no clue to the correspondence of location of the original and the resample will be furnished. This precaution, however, is of doubtful value against method (1), and resampling with a key-series of shifted numbers is not perfect protection, because of the difficulty of determining whether any discrepancy between the sample and the resample is due to fraud or to inaccurate sampling, handling, or assaying. The resampling method does reveal that some one of these conditions obtains; which one it is must be determined by a process of elimination through further sampling.

C. *Dummy samples.* The use of dummy samples should accompany every examination, not only because it is a means of discovering various types of fraud, but also to determine whether or not innocent salting has occurred. These dummies may be ore of known value, preferably low-grade; and if the ore used for this purpose is, or resembles, the ore of the mine under examination, so much the better. During the course of the examination, a dummy sample of considerable size should be crushed to about 20-mesh, and portions of this material carefully and repeatedly assayed, after which samples of it may be included, separately numbered and in separate sacks, to constitute a check. Fragments of low-grade ore or barren wall rock make the best dummy samples. Pieces of shale, grindstone, brick, or old concrete have been used for this purpose, but they are a little too obvious to be recommended. Dummy samples should of course be introduced, in separate sacks, into the series without the knowledge of outsiders. This precaution should aid in the detection of frauds listed under methods (2) through (8).

D. *Cutting of fresh face of ore.* Breaking down a clean face for sampling not only is a protection against method (1) but is also a manifestation that samples are being taken with care, and a notification to helpers to do good work.

If it is suspected that the rock face has been tampered with, any loose dirt taken off at the time of cleaning should be assayed; if this assay is abnormally high, it is a definite warning to the engineer. It may be necessary, in order to break down a clean face, to drill holes and blast with small charges of powder. If such blasting is done, then the sample should be taken at once, to prevent giving another opportunity to introduce fraudulent values.

If there has been any serious attempt to pick out barren spots or otherwise "dress" the mine, certain faces of ore will have a different appearance after a foot of rock has been blasted out; this changed appearance in many places in the mine should put the engineer on his guard.

E. *Personal attention to details.* This form of protection has been described as "a wary eye and a strong right arm." Complete personal attention to details would require that the engineer take all his samples alone or with the help of only proved assistants, and that he do all crushing, quartering, and assaying under the same conditions, thus guarding against salting by methods (2) through (5). Except in the examination of the smallest of prospects, this method is not adequate in itself. Even examining engineers must sleep, and if much sample-cutting is to be done, most of it must of necessity be left to others, some of whom may be in league with swindlers. However, constant watchfulness on the part of the engineer, who should never assume that attempts at salting are absent from any examination, is perhaps the chief safeguard against all forms of fraud.

F. *Panning samples.* When a sample has been taken and has been crushed, mixed, and quartered, and a portion sent to the assayer and another portion set aside for future reference, a prudent sampler will place a third portion in a common gold pan and wash it carefully. Panning results should be continually checked by sampling and assaying. Panning results alone tend to an overestimate of the value of the deposit. The final residue should be examined under a microscope. Such "salt" as local or placer gold, metallic filings, and gold or silver amalgam can be detected by this means (see photomicrograph of gold filings recovered from a salted sample, Fig. 3). If finely divided vein gold has been added with fradulent intent, the

fraud will be more difficult to detect. As a check on the accuracy of the panning, particles of fine lead may be added to the pan; the retention of these particles shows that the panning has been properly done. Panning should aid in detecting salting methods (1) through (8).

G. *Washing samples.* Another portion of some of the samples should be reserved and subjected to washing with distilled water. If gold chloride, gold cyanide, silver nitrate, or copper chloride solutions have been introduced into the samples, these will be to some extent dissolved in the distilled water and their presence will be revealed by an assay of the water. It is claimed, however, that if samples treated in this manner have been thoroughly dried, these substances will not dissolve in water. Washing of samples should aid in detecting salting methods (1) through (7).

H. *Checking of sampling with average value of production.* This safeguard is useful in many cases, especially in that of a fairly young mine where considerable development work, and perhaps some stoping, has been done and some or all of the ore broken has been milled or shipped to the smelter. The factors which would be in the engineer's hands before he finished the examination are: (*a*) the presumption that the material taken from the development and other openings was a fair sample of the ore and waste penetrated by these openings; (*b*) the volume and tonnage of ore and of waste from openings; (*c*) the tonnage of ore, waste, and tailing on the dumps; (*d*) the assay value of materials on the dumps; (*e*) the tonnage of ore or product shipped, and ore milled; (*f*) the value of the ore or product shipped; (*g*) the cubic feet per ton of ore in place and waste material.

All of these factors must be determined in the course of every mine examination, and may be used as a check against the results of sampling. The value of the ore or product shipped, plus the value of the ore, waste, and tailing on the dumps, is the total *value* taken from the mine. The tonnage of the ore or product shipped, plus the tonnage of the ore, waste, and tailing on the dumps, is the total *tonnage* taken from the mine. The total value divided by the total tonnage should give the average value of the material taken out, and this should be equal to the average value of the material remaining in the mine and the average value of the samples taken. Due allowance must be made, however, for the stage of development attained at the various levels and stopes relative to the positions of the ore shoots, and high- and low-grade sections, as shown by sampling.

Using the above designations, the following expressions should hold:

$$b = (e + c)g$$

$$\frac{cd + ef}{c + e} = \text{average value of material taken from openings}$$

The value thus determined should correspond to that discovered by sampling the remaining ore. If it does not, within the limits allowed, suspicion arises that the mine has been prepared for sale or that the values stated by the vendor are incorrect.

I. *Checking of mill runs by formulas.* Attempts to deceive during mill tests may not only involve insertion of values into the ore but may also involve juggling with tonnage figures. The chances of successful fraud during mill runs are considerably reduced by application of the formulas for percentage of recovery and ratio of concentration, as given previously on page 71 under "Metallurgical Study." These formulas should reveal any irregularity or mistake. It may not be easy to determine where the mistake lies, or whether it be fraud or error; but once a discrepancy has been discovered, the explanation must be sought until it is found.

J. *Examination of all parts of workings.* It is impossible to warn the young engineer too often to devote his earnest efforts to studying the bottom of the mine. Many men have made what they considered a careful examination without ever seeing the bottom of the mine in question. To leave oneself open to the results of such an oversight is folly.

Under no circumstances should the engineer take anyone's word that any particular spot or level under scrutiny is the bottom level. With pick in hand he should satisfy himself, before leaving the ground, that he has seen and felt, with no shadow of doubt, the virgin rock of the bottom, and has also seen every foot of the lower workings. If he is standing on what the owner terms the bottom level, and there is on that level a pile of loose rock or any spot otherwise covered, he must not assume that this is a temporary dump, but must clear it away and test the floor beneath. Such loose rock may mask an opening that leads further down, and much worked-out ground may extend below this "false bottom." The dead, empty shell of the whole deposit, or evidence of a change in quality or tenor of ore, might be concealed by a heap of loose rock five feet square.

If the lower workings of a mine have been fraudulently covered

up when a valuation was made, it would ordinarily have been necessary for the owner or his agent to represent matters falsely to the engineer; and therefore in these cases the purchasers ought to be able to recover their capital by suit when the fraud is ultimately discovered. But such legal proceedings, even when successful, are poor satisfaction to the engineer who valued the mine without seeing all the openings.

If a mine map which is represented as correct is furnished by the owner or manager, he should be tactfully requested to write upon such a map a signed and dated indorsement of its correctness. This is useful evidence in case of attempt to defraud.

Discovery of fraud.—If salting is suspected, ample opportunity should be given to the miscreants, but under such conditions that they may be detected. If a serious attempt is conclusively proved, the work of examination should stop, for no further time need be wasted in the sampling of a deposit that requires fraudulent methods to make it attractive to a buyer.

Until definite evidence of salting is in hand, the engineer should not endanger his friendly relations with residents by any display of suspicion or by setting obvious traps. Even if evidence is unearthed, however, it may be prudent, especially in remote regions, to avoid disclosing it until he feels safe from attacks by baffled swindlers who may seek revenge by physical violence. An instance of the lengths to which such vengeance may go is given by J. W. Ledoux in a discussion[10] of salting at the placers of Santo Domingo. In this account he mentions the deaths of five employees who were said to have died from fever, but whose deaths were attributed by rumor to poisoning because they knew too much.

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[10] Ledoux, J. W., "Placer Salting in Santo Domingo," *Engin. Min. Jour.,* Feb. 14, 1914, pp. 384–86.

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Chapter 5

Extension of Ore Deposits

When sample assays and measurements for all three dimensions—length, width, and height—of a block of ore are available, the average value of that block can be calculated, as will later be shown, to a fair degree of accuracy. When, however, it is necessary to estimate the probable extension of the orebody beyond or below the visible and measurable openings that can be sampled, the valuation of this estimated extension is attended by an increased margin of risk.

IMPORTANCE OF ECONOMIC GEOLOGY

The size and value of extensions that cannot be measured and sampled directly are of the utmost importance in mine valuation, and here as elsewhere, the engineer's duty leads him to apply his knowledge and experience in a careful study of all the factors, qualitative or quantitative, in an attempt to arrive at their magnitude. The source of knowledge upon which he may draw is embodied in the recorded observations and experience of the profession; the estimation of extension is a problem in economic geology. It is apparent that training in geology must be an important component of the mining engineer's general scientific equipment.

The task of the geologist.—In many quarters the labors and studies of the economic geologist are not yet fully appreciated. He is taunted, like many other men whose aim it is to apply advanced science to engineering and mining problems, with being altogether too commercial. On the other hand, other persons allege that his sole vocation is to inspect other people's handiwork and write voluminous reports couched in incomprehensible language; that he always comes after and not before the event of discovery; and that, although his theories may give an explanation of each particular deposit, they never help anyone to find orebodies. It is not surprising that such skeptics should be numerous among the so-called prac-

tical, otherwise uneducated, miners and managers; but they are not confined to these circles, for some men of high position in the mining and financial world assume the same attitude. The allegation that no direct practical result in the way of discovery of ore has ever followed the labors of an economic geologist can be disproved by a multitude of cases. Geological surveys do sometimes fail in their objects, but in the future they will more frequently prove to be first aids to the finding of orebodies. Grass-root deposits are easy to find, but almost all of them have already been exploited.

In the valuation of mines the forecasting of probable extensions of the orebodies beyond existing openings is a task for the economic geologist or an engineer trained in this branch. Much of what is said here with respect to economic geology and mine valuation applies with equal force to prospecting and to the development and operation of mines.

The proper procedure is first to make a complete instrumental survey and map of the mine. As Brunton states:

> After the completion of the map, it should be made the beginning of another, and in most cases a far more important undertaking, namely, its utilization as a starting-point for a complete inventory of the company's underground possessions. The ordinary mine-survey map, being nothing but a record of what has been done, is, in one sense, only ancient history. To increase its value such additions should be made as will render it a complete statement of the amount and value of ore in sight at any particular time, and a guide for future development. Comparatively little extra labor is involved in this undertaking, since the larger and more expensive part of the work has already been completed when the mine has been surveyed and mapped. The necessary additions consist in working out and platting on the maps, the geology of the mine as exposed in the workings, in such a manner that the geological survey may be of daily use in the development and operation of the mine.[1]

In order to put his observations to practical use the geologist should work in close co-operation with the sampler and the surveyor. In fact, as stated before, he may combine in his own person all three functions.

There seems to be dire need for repeated preachment against the too frequent sad neglect of instrumental surveying and mapping in geological surveys. By carefully examining each face frequently, a geologic map can be kept up to date and will be of the first order

[1] Brunton, D. W., "Geological Mine-Maps and Sections," *Trans. A.I.M. & M.E.*, Vol. 36 (1906), pp. 508–40. The article contains fourteen tracings of horizontal and vertical sections of an imaginary mine.

of importance in the direction of the sampling or development work.

The horizontal mine plans should be made to a convenient scale on tracing paper or cloth; the vertical distance between horizontal sections should usually be that of the distance between the levels, but for some mines much closer intervals are used. The only complete horizontal section available for study is the surface, and even this is at times covered with soil; it should therefore be studied with especial care. All other horizontal sections are mere scraps of the whole.

A careful examination of the surface should be made early, and the geology underground should be connected with that of the surface, and correlated to the general geology of the surrounding district. This surface geologic map should be fixed on an accurate topographic survey. In cases where there are government geological surveys these can be enlarged to a suitable scale, but they should be checked carefully and the limits of the different formations should be determined with greater accuracy than exists in some of these maps.

The task of geologic control of mining operations is one demanding the utmost carefulness and thoroughness of observation, and, if genius is infinite capacity for taking pains, the mine geologist should be the greatest genius on the staff. Much of his work will be done underground, in artificial light, where rocks and minerals have an appearance entirely different from that above ground. Many mining engineers remember their early struggles to recognize even gold ore by candlelight. Fortunately, in recent years the acetylene lamp and the electric hand lamp have greatly decreased the difficulty and increased the accuracy and range of underground mineralogical observation. The underground workings are generally covered with a thin coating of mud after the face has progressed a few feet beyond any particular point. It is important therefore for the geologist to see each face in the mine after each blast has cleared away and the loose rocks have been barred down, and to record the observations at once. Observations should be taken frequently, not only for the purpose of insuring accuracy and completeness but also to correct any mistakes in sampling or development and to secure the benefit of advantageous procedure before useless work is done or time lost.

These geologic maps should show all the facts, no matter how pleasant or unpleasant, plainly and without ambiguity. The bad

habit of indicating by full lines the probable extensions of ore may be unqualifiedly condemned, because an uninformed person might mistake these conjectures for facts. In setting down the facts in his notes and upon the mine maps the engineer will also do well not to play the dangerous game of trying to distinguish between important and unimportant facts. A fact is a fact, and supposedly unimportant observations of today, properly recorded, may tomorrow become the key to a situation. The drawing of conclusions and inferences from the observed facts by the engineer should be confined wholly to his reports to his client, leaving his mine maps and notebooks unembellished by any beautiful conjecture.

The engineer has a large task ahead of him in his detailed geologic inspection of all the open workings. He should with his own eyes see every square foot of the sides and roof of all the stopes, drifts, winzes, and crosscuts. If he misses a spot the size of a man's hand, that spot may contain, back of the film of dust and mud covering it, the secret of the ages. Of all books, the geologic book is the one which the conscientious devotee must scan and ponder with the greatest care. A small microscopic crystal may contain evidence, hitherto undetected, of the sequence of replacement, or the alteration of the country rock with depth, which may presage the widening and enriching of the orebody with depth and thus herald the glad tidings of wonderful discoveries to the speculators; or it may be the first tiny whisper of coming impoverishment which will eventually send the shares down with a thud. All observations should be fixed by accurate instrumental survey, as cases can arise where the definite determination in space to the inch may be pertinent to the ultimate conclusion.

Risk in estimating ore.—The extensions of coal, petroleum, and certain bedded and placer deposits may be predicted with much certainty; the geology of these deposits is not complex, their extent is almost always considerable, and their limits are determinable. But in the case of metalliferous lode deposits there are almost unlimited chances for error in estimates of extension beyond the visible faces of ore. If the estimated future profit from the ore that has been proved by sampling and measurement will yield a certain sum sufficient to cover the three requirements epitomized at the end of chapter 2, then all ore discovered in the future will, of course, return an enhanced profit; though mines with assured profits and good expectations are seldom on the market.

The determination of a just price for a mine depends in most

cases upon the allowance that is made by the engineer for "probable" ore. Suppose he has carefully sampled a face of ore at the end of the longest drift or at the bottom of a mine, and that the assay yielded a value of $5 a ton. Although the experienced engineer may hazard a shrewd guess as to the continuity of the ore, he can see through a wall of rock no further than anyone else. He may stake his professional reputation that the $5 value will extend for at least an inch beyond the openings; he will risk little if he assumes that it will extend for one foot; but very few careful engineers will venture to predict, without some qualification, an extension of one hundred feet. Somewhere between the limits of one foot and one hundred feet he must set a point that will define the boundaries of the block of "probable" ore that must be taken into account in answering the ever-present question: "Will it pay?" In most mines, even if the judgment on the volume of expected ore is liberal in the extreme, this volume will still be insufficient to constitute a property worth the asking price.

GEOLOGIC FACTORS IN ESTIMATING ORE EXTENSION

Since the hazards of estimating the continuity and quality of ore deposits beyond the visible and measurable openings may be lessened by an understanding of the principles of economic geology, some geological factors affecting the extension of metallic ore deposits must here be mentioned. This subject forms the basis of an immense body of knowledge, and it is obvious that its innumerable ramifications can merely be touched upon in the present chapter. It is proposed merely to give an acceptable classification of ore deposits and then to discuss a few of the most important geologic factors and their possible influence in the extension or existence of probable ore. The student is presumed to have some knowledge of elementary economic geology and to have taken the introductory courses in geology; for further information on this important field in its relation to mining economy, he is referred to the bibliography at the end of this chapter.

Fundamental concepts.—It will be useful to state and define some elementary geological and mining concepts that must be kept in mind when considering the extension of metallic ore deposits.

Metals occur in nature either in the form of free (or virgin) metal or, more commonly, in combination with other elements, especially as oxides, sulphides, and chlorides. Ore deposits are more or

less rich concentrations of minerals formed by certain physical and chemical interactions in the earth's crust, and are to be found in greatest concentration in the upper portions. The chief agency in the formation of primary metal deposits is the circulation of aqueous solutions through fissures in the earth's crust, especially where that crust consists of permeable beds, shattered belts, or rocks with easily decomposed and replaceable components—forming in the last case *in situ* (primary) deposits. Secondary deposits are formed by denudation and concentration of the minerals at the surface of the earth.

Primary ore may be altered under certain conditions to produce zones of impoverishment (by leaching) and zones of secondary enrichment (by deposition). The possibility of encountering a zone of secondary enrichment may have a fundamental bearing upon the value of an extension estimated to lie beyond a certain sampled face in a mine only superficially developed.

The terms "reef" and "ledge" are in common usage virtually synonymous with "vein." "Gash" veins are often formed by the deposition of minerals in shrinkage cracks in igneous masses, and are notoriously unreliable when one investigates their continuity in either depth or length. An aggregation of veins in a wide formation is often called a "lode" or a lode formation, although lode is often used synonymously with vein. A "dike" differs from a vein in that it is formed by the intrusion of igneous fluid or molten matter into a fissure; these intrusions are seldom of economic importance. "Reef" refers to bedded deposits such as those of South Africa. That portion of a vein, lode, or reef which may have economic value is termed the "ore shoot." "Float" is debris from a lode transported from the original site and found on (or near) the surface. The "hanging wall" is the wall rock overlying the lode; the "foot wall" is the wall rock underlying it.

Classification of metal deposits.—Ore deposits have been classified by a number of authorities. Although neither color nor shape of themselves form the basis of a useful modern classification, both were so used at the beginning of mining science; one of the earliest systems, that of Agricola,[2] about 1550 A.D., was based entirely on shape. At the present day a knowledge of the shape of a deposit is primarily useful in determining the method of mining to be used. An interesting theory of color classification is that recently pro-

[2] Agricola, Georgius, *De Re Metallica.*

pounded by Locke[3] in his discussion of outcroppings; in this case color is considered a valuable guide in prospecting.

A review of the principal systems of ore deposition is given by Kemp.[4] The latter is also responsible for a condensed classification to be found on page 97 of Peele's *Handbook,* which should be studied carefully to supplement the present description. One of the latest classifications is that of Emmons.[5] An elaborate system outlined by Lindgren[6] has the advantage of giving a large number of examples of each type of mineral according to its industrial use. Maclaren[7] presents a classification of gold deposits which is useful in explaining the probable depth to which such deposits may attain.

The most useful basis of classification is that of origin, although many deposits of obscure origin are still the subjects of controversy. The physical and chemical actions that result in the formation of mineral deposits have been listed by Young as follows:

CLASSIFICATION OF ORE AND MINERAL DEPOSITS[8]

		Metalliferous	Non-Metalliferous
I. Deposits due to weathering and erosion	*In situ* or close proximity to source	Iron ores	Residual clays
		Manganese ores	Bauxite
		Gold	Phosphates
		Tin	Barite
		Platinum	Ochers
	Eroded and transported to a distance	Gold placers	Detrital clays
		Tin placers	Quartz sand
		Platinum placers	Fuller's earth
		Monazite and rare earths	Gem stones
		Magnetite	

[3] Locke, Augustus, *Leached Outcrops as Guides to Copper Ore.*

[4] Kemp, J. F., *The Ore Deposits of the United States and Canada,* 3d ed., Appendix I.

[5] Emmons, W. H., "The Enrichment of Ore Deposits," *U.S. Geol. Survey Bull. 625,* pp. 16–17.

[6] Lindgren, Waldemar, *Mineral Deposits,* p. 189.

[7] Maclaren, Malcolm, "The Persistence of Ore in Depth," *Min. Sci. Press,* April 4, 1914, pp. 566–70.

[8] Young, George J., *Elements of Mining,* 2d ed., p. 10.

CLASSIFICATION OF ORE AND MINERAL DEPOSITS (*Continued*)

		Metalliferous	Non-Metalliferous
II. Deposits concentrated in bodies of surface waters	By precipitation	Bog iron and manganese ores Oölitic iron ores Carbonate iron ores	Limestone Chalk Dolomite Phosphate beds
	By evaporation		Salt Gypsum Sodium sulphate Sodium bicarbonate Borax Potash minerals
	By sedimentation		Peat Lignite Coal Diatomaceous earths
III. Deposits concentrated by circulating ground waters	Derived from rock masses	Iron ores Ores of copper, lead, vanadium, zinc	Barite Sulphur(?) Magnesite Talc Soapstone Asbestos Gypsum Sodium nitrate Nitrates Borax
	Derived from primary deposits	Secondary and sulphide enrichment Copper, gold, silver	
IV. Deposits formed by ascending heated waters associated with igneous intrusions		Ores of mercury, antimony, gold, silver, lead, tin, zinc, copper, tungsten, molybdenum	Quartz Calcite Alunite Borax(?)

Classification of Ore and Mineral Deposits (*Concluded*)

		Metalliferous	Non-Metalliferous
V. Deposits due to metamorphism		Ores of copper, iron, lead, zinc, tin	Garnet Graphite Corundum
VI. Deposits formed in magmas	Segregations	Magnetite Chalcopyrite Arsenopyrite Platinum Cassiterite Chromite Nickeliferous sulphides	Corundum Diamond
	Pegmatite dikes	Cassiterite Wolframite Columbite Molybdenite Rare minerals	Feldspar Mica Apatite Lepidolite Zircon Gem stones

The chief value of a correct classification of the origin of a mineral deposit is that it encourages a better understanding of the nature of the deposit and enables a comparison to be made with similar deposits elsewhere. The mere attempt to fit the deposit into any logical classification will lead to an organized study that cannot fail to enlarge the engineer's knowledge of his immediate problem. It should be noted that some geologists are becoming skeptical of magmatic segregation as the genesis of such deposits as those of International Nickel.

Period of formation.—Although geological age is of less importance in the study of metal deposits than in the study of sedimentary deposits, much information concerning probable extension can be obtained from a classification on the basis of age.[9]

Size, shape, and structure of deposit.—The size, shape, and structure of an orebody, in so far as these are determinable, are of first importance in estimating probable extension with depth.

The prospector or owner usually has the belief that the vein he has located extends to the middle of the earth; "she grows wider and richer as she goes down" is the settled conviction of many; and the very least depth that the prospector will admit for his mine is that the ore shoot is about as deep as it is long. Some deposits do gain in value for certain increments of depth, but apart from those

[9] See Young, George J., *Elements of Mining,* 2d ed., pp. 20–21.

subject to leaching such deposits are few. Some have horizontal zones, alternately rich and poor, or containing different minerals, depending on the strata or rock the lode is traversing.

A study of the shape of many ore shoots shows that the lower boundary does not usually end abruptly but gradually narrows or splits up into a number of fangs. Any barren spots on the lower level of a mine must be viewed with suspicion, as they may perhaps presage the breaking up of the ore shoot into fangs.

Most metallic ore deposits were formed through the agency of circulating solutions, by the deposition of minerals in fissures occurring in the earth's crust. For this reason, any condition which affects the formation or alteration of the fissures or folds in the wall rock will determine the course and extent of the ore shoot in such fissures. One of these conditions is faulting of the vein, which may so dislocate the course of the ore shoot that determination of its extension is difficult, even supposing such extension exists. The occurrence of "horses" or other erratic masses of country rock in the lode may considerably affect the quantity of ore that is estimated to lie within a given section.

The distribution of the ore may vary from a more or less uniform value throughout to a series of high-grade lenses, shoots, pockets, or kidneys, and in the more patchy and erratic types of orebodies, predictions as to extension of ore beyond developed areas are difficult and risky.

The folding and faulting of the vein or bed, and the variations in the nature of the country rock, must all be placed on the geologic map as exactly as possible, to enable the making of cross-sections of the vein and surrounding country.

The occurrence of cross-veins may greatly enrich the deposit; bonanzas are often found at the intersection of two or more veins, since solutions from different sources were probably here mingled and may have caused abnormal local deposition of metals or minerals. It is more difficult to understand why the intersection of a barren vein with a minute crack in the rocks should give rise to "pockets" of rich gold quartz, but the pocket miners of California are well acquainted with this phenomenon and will follow a nearly barren quartz vein for hundreds of feet in search of such intersections; one pocket, near Sonora, yielded about $200,000 from a few wheelbarrow-loads of ore.

"Indicator veins," such as those at Ballarat, Australia, are similarly followed by miners in their search for pay ore, which occurs

when these veins intersect with quartz reefs. These indicator veins may extend for miles and preserve the same appearance for these long distances, although they may be given different names at various places. One of the most striking is the "pencil-mark," which, although merely a thin streak, may be followed for a long distance, and along its course gives rise to occasional valuable deposits.[10]

The wall rocks forming the boundaries of a deposit and in contact with it may determine its extent and richness. The types of influence which wall rocks may have on the deposit may be enumerated as follows:[11]

1. Solubility of wall rocks, and therefore their susceptibility to replacement.
2. Influence as a precipitating agent on solutions.
3. Influence as themselves a source of metals. The action of the wall rocks seems to be very clearly shown in Cornwall veins where tin and occasionally tungsten prevail in the lower levels in the granitic country rock, while in the upper levels copper was deposited in the slate. Lindgren, however, attributes this change in deposition to the difference in pressure and temperature at the time of formation, the slates being the cooler rock.
4. Texture of wall rocks may limit the form and profundity of the fracture. In homogeneous rocks the tendency is toward open, clear-cut fissures; friable rocks give rise to zones of brecciation; slates or schistose rocks enclose lenticular cavities.
5. Physical character of the rock mass and the dynamic forces brought to bear on it.

Mineralogical associations.—Long experience of miners has revealed that certain valuable minerals are often found in association with other minerals; thus, gold is typically found with quartz, and tin with the component minerals of pegmatoid dikes. Such wonted associations will, of course, serve as useful indications of the possible occurrence of valuable minerals. It does not follow that such association invariably exists—quartz does not always contain gold nor do pegmatoid dikes always contain tin—but every geologist or engineer will acquire the habit of carefully inspecting localities where he finds mineral formations known to be commonly associated with certain metals.

[10] Rickard, T. A., "The Indicator Vein, Ballarat, Australia," *Trans. A. I. Min. E.*, Vol. 30 (1900), pp. 1004–1019.

[11] Based upon Hoover, H. C., *Principles of Mining*, p. 24.

Alterations.—An important consideration is the likelihood of a change in the chemical composition of the ore at various depths. The zones of oxidized, semi-oxidized, secondary enrichment, and primary sulphide ores all present distinct metallurgical problems; while the oxidized surface ores may be cheaply worked by simple milling, the primary sulphides may need expensive concentrating and smelting plants.

The determination of the extent of leaching and of probable enrichment involves a study of the nature of the overlying gossan, the ground-water level and its movement, the rapidity of erosion, the nature and permeability of the rocks, and fracturing. Frequently these must be deduced from surface conditions alone, with no assistance from underground observations.

It should always be borne in mind that after an ore deposit in the process of geologic erosion is brought near the surface, both meteoric waters and surficial movements begin immediate alterations until the upper portions, at any rate, are so changed that the ore from deeper portions would not be recognized in comparison with a specimen from the upper levels of a given mine. If the mine is in the prospect stage there will probably be nothing but oxidized ore visible, and if there is no other evidence of the nature of the ore below the zone of oxidation the soundest procedure is to make a complete analysis of the oxidized ore. If the primary sulphide ore contains antimony or arsenic, such careful analysis will probably reveal traces of these constituents in the oxidized ore. Many disastrous mistakes have arisen from failure to foresee a change from an easily treated oxidized ore to a sulphide ore, which necessitated an increase in treatment costs and a reduction in recoverable percentage, although this can sometimes be obviated by the use of the flotation process or other modern methods. On the other hand, if the oxidized zone is of the copper or silver type, it may give warrant for expecting to encounter a valuable zone of secondary enrichment. An oxidized zone containing little of value may give place to a zone of secondary enrichment yielding a bountiful profit, which may then be followed by a zone of primary ore of the steady dividend type. It is to be noted that most "antiguas" have passed the zone of secondary enrichment.

Surface topography: outcrops.—When mineralizing action has been strong enough to form important orebodies, it is almost certain that such action will have greatly affected the rocks over a considerable area. For this reason a rich mine is usually found in a

highly mineralized district. Although surficial indications over most of such an area are usually too slight to be termed ore, these indications may serve to point the way to rich underlying deposits. Iron oxides in a large mass of igneous rock or schist, copper-stained iron oxides in limestone or other rocks, or interlacing or parallel veinlets of quartz far from the main vein all may help in locating a valuable deposit. But no matter how promising the outcrops in the locality of a vein may be, unless there is some general mineralization of the surrounding region it is unlikely that such outcrops will indicate the existence of an orebody that will develop into a great mine.

Although much may be learned from a study of an outcrop, inferences drawn from the outcrop alone are not conclusive. The size of the outcrop is likely to be very misleading. This is especially true of gold quartz veins; a great mass of quartz—the so-called "blow-out"—may show as a small hill perhaps a hundred feet wide, but development may reveal a vein only a few feet wide. On the other hand, many rich ore deposits give no sign whatever on the surface. This was true of several of the Tonopah silver mines, where rich ore was buried under several hundred feet of barren eruptive rocks. The conspicuous outcrops in Butte do not as a rule have large ore bodies below them. The large ore bodies almost invariably have inconspicuous outcrops.[12]

F. H. Probert[13] has collected a number of descriptions of outcrops of disseminated porphyry copper deposits, among which is a statement by J. E. Spurr:

> Strong copper staining at the surface is considered an unfavorable indication and is a symptom that the downward migration of the secondary copper zone has not been able to keep pace with the down-cutting erosion, so that part of the copper in the rocks is being carried away by the surface drainage while another part tends to scatter, seeking lower levels. Throughout the productive area, there are very few copper signs on the surface to indicate the remarkable chalcocite zone beneath.

Probert also remarks:

> Rock alteration is another helpful factor in sizing up the possibilities of a district. Advanced alteration, decomposition, and disintegration are reflected in the topography and areas of gentle slopes, or rounded hills, are more promising for large low-grade deposits than rugged country. Such a surface is also easier to mine by the modern methods devised for the extraction of

[12] Thomson, Francis A., lecture at the Montana School of Mines.

[13] Probert, Frank H., "Surficial Indications of Copper," *Min. Sci. Press*, Aug. 19, 1916, pp. 267–75.

large daily tonnage. . . . . The amount of surface coloring increases in the desert, partly on account of the more rapid oxidation, and partly because of the high evaporative factor. Then, too, arid sections are seldom forested, so that the coloring of mineral deposits is more conspicuous. Little or no difficulty will be found in recognizing the outcrop of veins, but the disseminated deposits must be more carefully studied. As a little oil will spread out over a large surface of water, so a little copper will stain a large land surface. It is often deceiving.

A brecciated vein, silicified shear-zone, or metamorphosed limestone will be more resistant than the enclosing rock and will weather out conspicuously in the landscape. In looking over a new district, all unusual features, such as steep scarps, rock-ribs, "blow-outs," and sudden changes of color, should be investigated.

J. E. Carne, also quoted by Probert, says of the copper deposits of New South Wales, Australia: "The surface staining is very delusive. The most favorable indications are cellular iron oxide and secondary quartz, but this is only presumptive evidence, and not an infallible guide."

The subject of outcrops offers an extensive field for research, and painstaking studies have led to results of practical importance. Augustus Locke[14] presents a lucid and comprehensive approach to the estimation of extension of orebodies below the visible surface. For the prediction of copper-bearing deposits he has established certain useful criteria based on the occurrence of iron oxides of both chemical and mechanical origin.

Ground-water level.—Closely allied to the study of outcrops is the determination of the ground-water level. This can seldom be discovered by surface indications. The value of some deposits depends largely on the amount of leaching and enrichment that has taken place. Such enrichment ceases at the permanent ground-water level, hence the importance of its determination. If the engineer cannot discover this by observation he must adopt some working assumption on which to base a decision that will be safe without being too conservative. Many helpful notes on the determination of ground-water level will be found in the literature of economic geology.

Probable depth.—It may be broadly stated that most important mineral deposits depend for their formation upon the existence of fissures through which water and gases may circulate. The exact depth at which such fissures may exist has been studied by many

[14] Locke, Augustus, *Leached Outcrops as Guides to Copper Ore.*

geologists. Van Hise,[15] in his treatise on metamorphism, has divided the outer part of the crust of the earth into three zones, depending on the nature of its deformation when subjected to stresses: an upper zone of fracture; a lower zone of flowage; and a middle zone of combined fracture and flowage. The openings in the rocks of the zone of fracture, which is near the surface, are comparatively stable because the weight of the overlying mass is less than that needed to crush the rock. At greater depths, where the stresses exceed the strength of the rock, openings, if formed, would be almost immediately closed by pressure. It is estimated that for all but the strongest rocks flowage would begin at depths not greater than five or six miles, although experiments by Adams indicate that cavities and fissures may exist at depths of eleven miles, or even deeper. From this view it seems possible that non-igneous mineral deposits might exist at depths of several miles, although other authorities hold that a depth of 20,000 feet is the limit of the zone of open cavities.[16] While these theoretical considerations are interesting, the extreme depths at which mining operation is practicable are much less than the theoretical depths of formation. Although gold is now profitably won from a depth of 7,600 feet in the Transvaal, it is quite safe to prophesy that a depth of 15,000 feet will never be exceeded in mining.

The depth to which ore deposits extend, then, varies greatly, but general experience shows that many base metal and some precious metal deposits cannot profitably be worked, because of a decrease in value, at a greater depth than 2,000 feet. Maclaren states[17] that the andesitic deposits of the Middle Tertiary, which have furnished some of the greatest bonanzas known, are not profitable below this depth. By far the deepest of these andesitic deposits are those of the Comstock Lode in Nevada, worked to a depth of 3,300 feet; but the ore in the lower workings was in no way comparable to the great bonanzas found between the 1,000- and 1,800-foot levels, and it is doubtful if any profit was made on work done below the 2,000-foot level. Only a few mines in the andesitic regions have carried rich ore below the 1,000-foot level, and many of them have become impoverished at between 500 and 1,000 feet, as was the case at

[15] Van Hise, C. R., "Some Principles Governing the Deposition of Ores," *Trans. A. I. Min. E.*, Vol. 30 (1900), pp. 27–177.

[16] Emmons, W. H., "The Enrichment of Ore Deposits," *U. S. Geol. Survey Bull. 625,* 1917, p. 44.

[17] Maclaren, Malcolm, "The Persistence of Ore in Depth," *Min. Sci. Press,* April 4, 1914, pp. 566–70.

Bodie. In some mines the fissure seems to be bottomed, although this is not true of all.

Recognition of the irregularity and lack of persistence of auriferous orebodies in andesitic fields is of prime importance to the mining engineer, and he should exercise the greatest caution in predicting the future of a mine in this class. Skilful Nevada miners long ago recognized the non-persistence of andesitic ores to considerable depths, and when a new discovery is made there the first question on the lips of all is: "Do you think it will go down?"

T. A. Rickard holds[18] that almost all mines become poorer with depth, but Maclaren maintains that geological structure and not depth is the factor controlling the persistence of ore.

The foregoing statements show that both theory and practice agree that the chances are poor for the profitable working of the majority of mines to great depths. The engineer's problem is to make an intelligent forecast of the depth to which the mine he is valuing may profitably be worked, and from this determination he can then estimate the amount of capital that can justifiably be employed; in order that he may make such a forecast, a sound knowledge of economic geology is imperative.

Geology of adjoining mines.—Mines near by should be visited and studied and maps of the surrounding district carefully examined, for through these means information can often be obtained that will be invaluable in estimating the course and extent of the orebody. Ore deposits in a given geologic district are, in the main, likely to be somewhat similar in longitudinal and vertical extent; they frequently also show some similarity in the shape and value of the ore shoots. In exceptional cases, a neighboring mine may even have development exposures on the same vein at a considerable depth below the mine that is being examined and so may provide the engineer with very useful information.

Stage of development.—The evidences of past production and past profits are of great use to the valuing engineer. It is essential to know whether this production and this profit were made from ore similar to that now found in the mine, or whether they were made from a quality or kind of ore now exhausted. Hence, it is of paramount importance for the engineer to be able to distinguish the various zones that are commonly encountered in mining; as, for

[18] Rickard, T. A., "Persistence of Ore in Depth," *Trans. Inst. Min. & Met.*, London, Vol. 24 (1914–15), pp. 4–46; discussion, pp. 46–190.

example, the zone of secondary enrichment in copper and lead-silver deposits, which zone is unmistakable to the trained eye. In copper deposits most of the metal has been removed from the oxidized zone by leaching and redeposited in the secondary zone.

If the mine opening penetrates deeply enough, the oxidized zone, the zone of secondary enrichment, and the zone of primary sulphides will all be exposed; but if the opening is shallow and exposes only the oxidized zone, the past experience of the engineer is the only aid to predicting the nature of the ore at a lower horizon. If the mine is in a district that has been widely exploited and an enriched zone has generally been encountered, it is probable that a shallow mine under investigation will develop a similar enrichment, and the thickness of the enrichment zone normal to the district should be investigated. If there are no neighboring mines that have been sunk to lower levels, prediction is dangerous, for it is not impossible to find a powerful and rich vein of oxidized ore without an enrichment zone or with a very shallow one which not only does not show a profitable sulphide vein beneath but changes into a wide zone of low-grade worthless pyritic ore.

GEOLOGIC MAPS

All the information obtained in the study of the mine and the ore deposit should be put on geologic maps. It will probably be necessary to make a number of these maps and plans, such as horizontal plans at various horizons, vertical sections, and projections on the plane of the vein. In some of the larger copper mines horizontal plans are made for every twelve feet of vertical depth.

These maps should contain an accurate record of each opening; on them should be marked the mineralogic and geologic data collected and the evidence revealed by the microscope and by chemical analysis. The more knowledge the engineer has when making such observations personally, the greater will be the certainty of his conclusions.

The construction of mine models, glass or solid, is a proper activity for the mine geologist or surveyor. An excellent discussion of the use and construction of such models is to be found in Peele's *Handbook,* 2d ed., pages 1458–62, which also gives a good bibliography of the subject.

The chief value of the map or model will be the indelible picture it imprints on the mind. As familiarity with the various factors

grows, an understanding develops which it is impossible to acquire without compiling such a record. The map may be likened to a picture puzzle: little idea of its meaning is obtained until several pieces are put together; then the significance grows, as more pieces, meaningless in themselves, are added; and at last a shrewd guess can often be made concerning the missing sections.

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Chapter 6

Ore Reserves

RISK IN ESTIMATING ORE

The student has no doubt already gathered, from references made to "probable" ore, that the engineer cannot predict the value of all parts of the ore shoot with equal assurance. In valuing an ore deposit various classes of ore must be segregated and listed separately; such a classification is made in order to indicate the degree of risk assumed in estimating the profit, if any exists, that may be derived from each class. The engineer, when so classifying the ore in a mine, must be guided by the returns from sampling and by the geological data acquired in his study of the deposit.

The risk in estimating ore in a mine depends upon how far the values disclosed by the samples may be assumed to penetrate into the rocks beyond the visible surface sampled. That the values will extend for some distance at least is certain; but whether this extension should be assumed, for purposes of calculation, to be one inch, one foot, ten feet, or one hundred feet, must be decided by application of the principles outlined in chapter 5.

CLASSIFICATION OF ORE

Ore that has been wholly or partly blocked out in order to determine its approximate quantity and value, and other ore in the mine that may reasonably be expected to exist, is commonly designated in mining literature under the heading of "ore reserves." Since the term "reserve" familiarly denotes, as in banking parlance, a store that must not be touched unless under necessity, its use in mining is misleading when applied to ore that is intended to be converted, as soon as possible, into a salable product. "Ore reserves," it is plain, should never be used in any mining report unless explicitly limited to a clearly defined category. In this book it will be understood to comprise the first two of the three classes of ore—*proved, probable,* and *prospective*—defined below.

Among the many terms that have been used in describing ore are: positive ore, profit in sight, ore developed, ore blocked out, ore developing, ore expectant, ore partly developed, ore in sight. The term "ore in sight" has been subject to great animadversion because of its wide abuse by unworthy promoters and incompetent, alleged engineers; and the importance of correct designation of classes of ore is shown by the extensive restrictions prescribed for the use of this term and adopted by the Council of the Institution of Mining and Metallurgy.[1] It is clear that whatever designation is used to describe the various classes of ore in a mine such designation should be unambiguous and should be accompanied by all data, especially drawings, upon which the classification is based.

Of all the systems proposed for the classification of ore on the basis of risk involved, the following[2] would seem to have the most merit: All ore in a mine is segregated, under this system, into *proved, probable,* or *prospective ore.* Proved and probable ore are the only classes commonly included in the designation, "ore reserves."

Proved ore.—If there is virtually no risk of failure in continuity between the faces sampled, or if a block is so extensively surrounded by sampled faces that risk is reduced to a minimum, the ore may be designated as "proved." A block sampled on four sides within reasonable distances of each other would assuredly be termed proved ore; and in many cases in which only three, or two sides, and even one side of the block has been sampled, it may be justifiable to classify the ore as proved if geological evidence indicates continuity.

A block sampled on one side. If a face of ore in a drive has been sampled at intervals of 5 feet over a length of 100 feet, the average value for the width exposed can be determined with a fair degree of accuracy; but little is certain as to how far this value persists beyond the visible face exposed. The sampled face might be considered as one side of a block extending at right angles to this face. A block of ore may also be conceived as lying on the vein and surrounding the sampled opening; in such a case, the block would

[1] *Trans. Inst. Min. & Met.,* London, Vol. 10 (1901–1902), p. 202. The resolution was an outgrowth of a paper by J. D. Kendall, "Ore in Sight," *Trans.,* Vol. 10, pp. 143–49; discussion, pp. 150–201. Both the paper and the discussion are of great interest and give many examples of mistakes and misrepresentations in describing ore reserves.

[2] Hoover, H. C., *Principles of Mining,* p. 19.

likewise be considered as sampled in one dimension, through the middle.

A block sampled on two sides. If development work has divided up the orebody into blocks by openings at various intervals, and more than one face of the block may be sampled, the risk of estimating extension is further reduced. These openings are commonly at least 100 feet apart, so that if a block 100 feet long and 100 feet high has been sampled along two dimensions, side and bottom, the accuracy of estimating it is to that extent increased.

A block sampled on three sides. The continuity of the fourth side of a block of ore sampled on three sides can be counted on with more certainty than if two sides or only one side can be sampled. Even in this case, however, there must exist some geological warrant for assuming complete continuity of value.

A block sampled on four sides. If the mine has reached such a stage of development that it contains blocks of ore which can be sampled on four sides—as, for instance, a block bounded by two levels and two connecting winzes — then the risks of continuity within the block are reduced to a minimum. Even then, if the ore is "spotty" or heterogeneous, or if the deposit is one in which there are large inclusions of barren wall rock, or pinches in the vein, all these factors must be given a sensed weight in estimating the value of extensions between the sampled faces.

Samples taken on levels are likely to be more reliable than samples taken on raises or winzes. Levels are usually spaced at equal intervals, while raises and winzes often follow rich spots and are unevenly spaced. In a mine where the ore occurs as a series of shoots, and these shoots are inclined at 45 degrees or more, it can be shown mathematically that samples from winzes should not be included when calculating averages, for a large portion of the winze may lie outside the boundaries of the ore shoot. In such a case the present method would need to be applied with discretion.

Blocks of ore included under one of the four above headings may, then, be termed "proved" if mineralogical and geological evidence indicates continuity beyond or between the sampled faces. Strict logic would probably not allow any ore to be termed proved until it had passed through the mill; however, for engineering purposes, the term is useful for designating ore that may with a minimal risk be assumed to exist and to possess measurable value.

Probable ore.—If the risk factor is greater than that indicated for proved ore, but there is sufficient warrant for assuming continuity,

the ore may be classified as "probable." As the examination of the mine proceeds and maps are completed, blocks of ore lying beyond the boundaries of the blocks of proved ore will be revealed. Such blocks, although they cannot be sampled, may be included as part of the ore reserves if, in the engineer's opinion, the geological evidence is favorable.

In the last analysis the engineer must shoulder the responsibility of including in his estimate of ore reserves blocks of ore that are sensed to exist. He will be guided in taking this responsibility by his personal judgment, backed by his professional education and geological and mineralogical experience. Extension of ore is a factor that cannot be measured and evaluated in exact quantitative terms—if it could, there would be no great demand for engineers of known experience and ability.

Prospective ore.—Any conjectural ore which cannot be classified as proved or probable, and which cannot be stated in terms of tonnage and value, should be listed as "prospective," and should be considered as purely speculative when any valuation of a mine is made. It should never be listed under "ore reserves." In general, prospective ore is considered to be that lying well below the openings at the bottom of the mine and, in rare cases, that lying a little way beyond the ends of drifts. If development work shows good evidence of extension and the distribution of mineral in the vein is apparently regular, the estimates of prospective ore may be reasonably increased.

Unprofitable sections.—If large blocks of low-grade material have been mapped out, the possibility of leaving such sections untouched should be considered. If such blocks are small and are covered by a few samples only, it may be necessary to mine this material in any case, in order to obtain access to richer portions. But it should be recalled that any sampled block which has an assay value less than the operating cost of realizing upon its metal content is not *ore,* in the strict sense of the word, and every ton of such rock that is mined will result in an actual loss.

USE OF CLASSIFICATION

The system which has just been outlined cannot be used without qualification, for the requirements of proved ore will vary for each type of deposit, and, indeed, for each mine. Geological factors may be so favorable that a block sampled on one side only may justifiably

be termed proved ore, while the ore in a block sampled on four sides may be so erratic that the interior may be regarded merely as probable ore.

CALCULATION OF ORE RESERVES

The simplest manner of demonstrating the method used in the calculation of ore reserves after the engineer has collected geological, sampling, and assay data is to work out a number of hypothetical examples involving average widths, average values, and gross tonnage of ore reserves in a particular mine.

Average width and average value.—The formulas used to calculate the average width of vein and the average value of ore at a given site are:

$$\text{Average width of vein} = \frac{\text{Sum of widths}}{\text{Number of samples}}$$

$$\text{Average value of ore} = \frac{\text{Sum of (widths} \times \text{values)}}{\text{Sum of widths}}$$

EXAMPLE 1

The simplest possible hypothetical case one could assume is the calculation of the average width and average value from two samples, Nos. 1 and 2, taken, say, five feet apart on the side or roof of a tunnel following a vein. The measurements and assay values are given in Table 1.[8]

TABLE 1

CALCULATION OF AVERAGE WIDTH AND VALUE FROM TWO SAMPLES

Number of Sample	Width of Vein in Feet	Value in Dollars per Ton	Width × Value (Foot-Dollars)
1	5	25	*125*
2	6	15	*90*
Sum	*11*		*215*
Average	*5.5*	*19.55*	

[8] In this table and all other computations included in this section, figures giving such original observations as measurements, weights, and analyses are shown in roman type, and calculated figures are shown in italic type. Calculations are carried out to more places than are warranted by the reliability of original data. The existence of error is indicated by the ± sign, and "illogical precision" (see p. 222) will later be avoided by stating the result in round numbers.

The averages shown are calculated by substituting in the given formulas:

$$\text{Average width of vein} = 11 \div 2 = \mathit{5.5} \pm \textit{feet}$$

$$\text{Average value of ore} = 215 \div 11 = \mathit{\$19.55} \pm$$

This process obtains the value by using a weighted average proportionate to the width sampled. It is more accurate than the simple average that would probably be used by the tyro presented with the problem of determining the average value of two samples of $25 and $15 per ton. He would presumably not take the factor of width into consideration but would add the two values and divide by the number of samples. In this example, $25 + $15 = *$40* ÷ 2 = *$20,* which, compared with a result of $19.55 obtained by using the weighted method, would be in error to the extent of 45 cents per ton too high.

Although this error may seem trivial and unimportant in the hypothetical instance cited for illustration, the accumulated error in estimating ore in a mine where widths and values vary greatly would be large. The method of taking into account the measured width—one of the three dimensions used in computing the cubic contents of the ore sampled—furnishes a simple and sufficiently accurate means of obtaining a reliable, weighted average value of the sampled ore.

EXAMPLE 2

A more complicated hypothetical example will serve to show how the engineer, after obtaining necessary data, will calculate the average width and value for a 100-foot tunnel or drive following a vein. Suppose that ten samples across the true width of the vein have been taken ten feet apart along the tunnel. The value of each sample in dollars per ton has been given by the assayer, and widths and values are those given in Table 2. It is desired to know the average value of the ore sampled in the tunnel.

Using the figures given in Table 2, and applying the same formulas as in Example 1:

$$\text{Average width of vein} = 49.2 \div 10 = \mathit{4.92} \pm \textit{feet}$$

$$\text{Average value of ore} = 429.66 \div 49.2 = \mathit{\$8.73} \pm$$

By the erroneous method of the tyro, the average value would be $9 per ton.

TABLE 2

CALCULATION OF AVERAGE WIDTH AND VALUE FROM TEN SAMPLES ALONG A TUNNEL

Number of Sample	Width of Vein in Feet	Value in Dollars per Ton	Width × Value (Foot-Dollars)
1	4.3	12.00	*51.60*
2	4.5	10.98	*49.41*
3	5.6	11.72	*65.63*
4	5.3	9.82	*52.05*
5	6.2	7.89	*48.92*
6	5.1	5.68	*28.97*
7	6.3	4.75	*29.93*
8	3.2	12.35	*39.52*
9	3.9	8.35	*32.57*
10	4.8	6.47	*31.06*
Sum	*49.2*		*429.66*
Average	*4.92*	*8.73*	

Average width and value of a block of ore.—The same method may be extended to include calculation of the average width and average value of a block of ore bounded, say, by two levels and two winzes or raises.

EXAMPLE 3

Suppose that four openings bounding a block of ore have been sampled at ten-foot intervals and the averages for each opening calculated in the manner of Example 2. These four openings consist of two levels, A and B, each 200 feet long, connected by two winzes, C and D, each 100 feet high. We assume that the average width and average value of the samples taken along each of these four openings have been computed, as in Example 2, and these averages are set out as in Table 3 (p. 116). It is now possible to combine these calculated averages into a calculated average width and average value of the ore in the block bounded by levels A and B and winzes C and D.

A third factor, length, must here be taken into account, and the formulas become:

$$\text{Average width of vein} = \frac{\text{Sum (lengths} \times \text{widths)}}{\text{Sum of lengths}}$$

$$\text{Average value of ore} = \frac{\text{Sum (lengths} \times \text{widths} \times \text{value)}}{\text{Sum (lengths} \times \text{widths)}}$$

and

$$\text{Tons of ore in block} = \frac{\text{Length} \times \text{height} \times \text{average width (in feet)}}{\text{Number of cubic feet of ore in one ton}}$$

Substituting the summations of Table 3, the following results are obtained:

$$\text{Average width} = 3{,}640 \div 600 = \mathit{6.07} \pm \textit{feet}$$

$$\text{Average value of ore} = 29{,}277.30 \div 3{,}640 = \mathit{\$8.04} \pm$$

Assuming that specific gravity determinations previously made and recorded show that fifteen cubic feet of this ore will average one ton, then:

$$\text{Tons in block} = (200 \times 100 \times 6.07) \div 15 = \mathit{8{,}093} \pm \textit{tons}$$

TABLE 3

CALCULATION OF AVERAGE WIDTH, AVERAGE VALUE, AND TONNAGE OF A BLOCK OF ORE

Opening	Length in Feet	Average Width of Vein in Feet	Average Value in Dollars per Ton	Length × Width in Feet	Length × Width × Value
Level A	200	7.4	6.42	*1,480*	*9,501.60*
Level B	200	5.3	9.34	*1,060*	*9,900.40*
Winze C	100	5.1	10.71	*510*	*5,462.10*
Winze D	100	5.9	7.48	*590*	*4,413.20*
Sum	*600*			*3,640*	*29,277.30*
Average		*6.07*	*8.04*		

Average width and value of a block sampled on two sides.— The average width and value of the ore in a block may be calculated from a set of samples taken when it was not possible to sample the block along more than two openings—a tunnel on one side, say, and a raise on another side.

EXAMPLE 4

The average widths and values of level A and raise C, each 100 feet in length, are given in Table 4. The average width, average value, and tons of ore in the block are calculated by the same method as used in Example 3.

TABLE 4

CALCULATION OF AVERAGE WIDTH, AVERAGE VALUE, AND TONNAGE OF A BLOCK OF ORE SAMPLED ON TWO SIDES

Opening	Length in Feet	Average Width of Vein in Feet	Average Value in Dollars per Ton	Length × Width in Feet	Length × Width × Value
Level A	100	7.4	6.50	*740*	*4,810.00*
Raise C	100	5.3	12.60	*530*	*6,678.00*
Sum	*200*			*1,270*	*11,488.00*
Average		*6.35*	*9.05*		

Using the same formulas as in Example 3:

Average width $= 1{,}270 \div 200 =$ *6.35 ± feet*

Average value of ore $= 11{,}488 \div 1{,}270 =$ *\$9.05 ±*

Tons in block $= (100 \times 100 \times 6.35) \div 15 =$ *4,233 ± tons*

It should be noted that the practical assumption made in this example is that the assays and widths found in level A and raise C will extend over the entire block. Such an assumption should not be made, of course, without due support from geologic and mineralogic evidence.

Proved ore.—It is now possible, by using the method of calculating average value and tonnage of a block of ore shown above, to estimate the ore reserves in a whole mine where development work is sufficiently advanced to divide the ore into blocks which may be classified as proved, probable, and prospective ore. To illustrate this calculation, a hypothetical mine, shown in Figure 4 (p. 118), will serve to show the principles of estimating ore reserves, and will be used as a basis for the remaining examples in this chapter.

The mine sketched in Figure 4 represents no actual operating mine, but is rather presented as a hypothetical case in order to simplify the problem. The student should be warned again that such a simple example will seldom, if ever, be found in practice. For instance, it would be rare to find a mine this fully developed from which no ore had been stoped out in the upper levels. However, it would only complicate the example to shade off certain blocks as "stoped out," and then to dismiss such blocks from the calculation.

The case will further be simplified by assuming that the mine produces a single metal and that the amount of metal per ton has been reduced to dollars in the assay values given. It is not possible to

state assay values in dollars per ton without assuming a certain price for the metal product, except in the instance of a gold mine, where the price, in normal times, is fixed by law (see chapter 10). It will therefore be simpler to assume that the mine under discussion produces one metal, gold. Ordinarily the profit to be made in mines will vary for each different metal the ore contains, and will also vary for each type of ore—shipping, smelting, or milling ores, for example—and parallel computations will therefore be made for each kind and type of product. Such a complicated case, dealing with a base-metal mine yielding three metals, will be given in chapter 10 (Example 8).

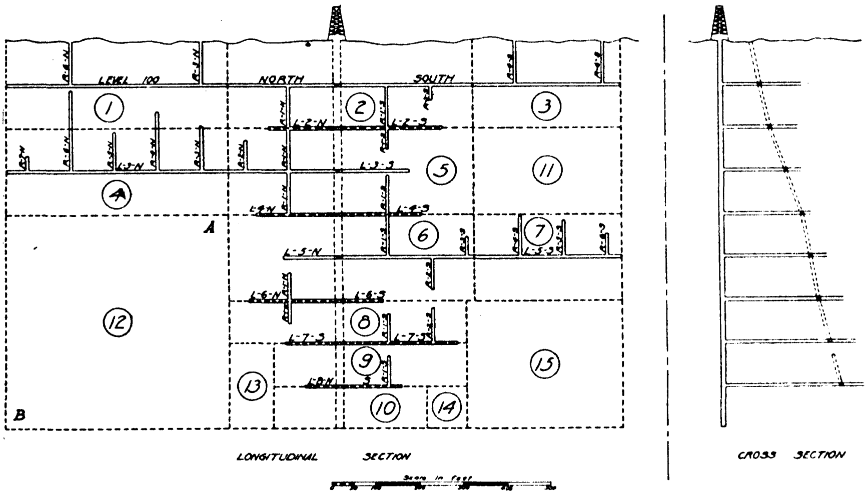

FIG. 4.—Sketch of Hypothetical Mine Laid Out in Blocks of Ore

The mine shown in Figure 4 has been opened up by a vertical shaft driven 890 feet in the foot wall. Crosscuts, 100 feet apart down this vertical shaft, run west to intersect the vein at distances of 125 feet to 425 feet from the shaft. From these crosscuts levels have been driven on the vein north and south to varying distances, as shown in the sketch. The ends of levels 100 North and 100 South, it is assumed, reach the end of the pay-ore as do the ends of levels 300-N and 500-S. The ends of all the other levels, it is assumed, showed no alarmingly low sampled values or widths of vein, and are assumed to be still within the limits of the pay-ore.

All the raises and winzes, partially or completely excavated, shown in the sketch are assumed to lie in ore of acceptable widths and values, as shown by sampling. All openings developed are assumed to have been sampled at intervals of ten feet, and the measured widths are true widths, or have been corrected to obtain true widths.

EXAMPLE 5

All the levels, raises, and winzes in the mine shown in Figure 4 have been sampled and the results of sampling, measurement, and assaying for ten blocks designated as proved ore are given in Table 5. It is desired to calculate the total tonnage, average width of vein, and average value of all the proved ore in the mine—that is, in these ten blocks.

First, the areas that may be classified as proved ore must be blocked out. For the purpose of this example it is proposed that in no case will the risk be taken of assuming continuity of proved value beyond one hundred feet from a sampled opening. The blocks of proved ore may be delimited in several ways even under this restriction, but in order not to make the problem too complicated the proved ore is taken to be all ore included in blocks 1–10 shown on Figure 4.

TABLE 5

CALCULATION OF AVERAGE WIDTH, AVERAGE VALUE, AND TONNAGE OF TEN BLOCKS OF PROVED ORE IN A MINE

Block	Length in Feet	Height in Feet	Average Width of Vein in Feet	Average Value in Dollars Per Ton	Length × Height in Feet	Length × Height × Width	Length × Height × Width × Value
1	510	190	6.7	7.14	*96,900*	*649,230*	*4,635,502*
2	560	190	5.8	10.16	*106,400*	*617,120*	*6,269,939*
3	320	190	6.2	9.28	*60,800*	*376,960*	*3,498,189*
4	510	200	7.1	11.46	*102,000*	*724,200*	*8,299,332*
5	560	200	6.3	8.43	*112,000*	*705,600*	*5,948,208*
6	560	200	5.9	9.74	*112,000*	*660,800*	*6,436,192*
7	320	200	5.2	12.68	*64,000*	*332,800*	*4,219,904*
8	550	100	5.4	8.43	*55,000*	*297,000*	*2,503,710*
9	460	100	6.2	9.74	*46,000*	*285,200*	*2,777,848*
10	370	90	6.5	10.58	*33,300*	*216,450*	*2,290,041*
Sum					*788,400*	*4,865,360*	*46,878,865*
Average ...			*6.17*	*9.64*			

The formulas used to calculate the average width, average value, and tonnage of a number of blocks of ore are:

$$\text{Average width of vein} = \frac{\text{Sum (length} \times \text{height} \times \text{width)}}{\text{Sum (length} \times \text{height)}}$$

$$\text{Average value of ore} = \frac{\text{Sum (length} \times \text{height} \times \text{width} \times \text{value)}}{\text{Sum (length} \times \text{height} \times \text{width)}}$$

$$\text{Total tonnage} = \frac{\text{Sum (length} \times \text{height} \times \text{width)}}{\text{Number of cubic feet of ore in one ton}}$$

Substituting the summations found in Table 5, the averages and tonnage of all the proved ore in the mine become:

Average width of vein $= 4{,}865{,}360 \div 788{,}400 =$ *6.17 ± feet*

Average value of ore $= 46{,}878{,}865 \div 4{,}865{,}360 =$ *$9.64 ±*

Tons of proved ore $= 4{,}865{,}360 \div 15 =$ *324,357 ± tons*

The proved ore in the mine, all of which is presumed to be included in blocks 1–10, is thus estimated to be 324,357 tons, having an average value of $9.64 per ton, with the average width of vein of 6.17 feet.

Probable ore.—The tonnage and value of proved ore in the mine constitute the total value of only that portion assumed to have a minimal risk of continuity. There may be also present, however, a volume of ore that is reasonably likely to yield a profit; in other words, probable ore which may be expressed in terms of tonnage and value.

In the mine shown in Figure 4, levels 100 North, 100 South, 300-N, and 500-S have been sampled to the point where the ore shoot fails, but it is assumed there is no indication that not all other openings lie in the vein, and there is no sign of "bottoming." In this case, then, it is proposed, for the purpose of illustrating the method, to define *probable* ore as all ore more than 100 feet from any opening, but lying within the boundaries of a large rectangular block, 1,390 feet long and 880 feet deep; these dimensions are the maximum length of the ore shoot and a depth of 90 feet below the lowest sampled working. Following this definition, the probable ore in the mine will include the ore lying in blocks 11–15 in Figure 4.

The lengths and heights of these five blocks of probable ore may be measured on the sketch. Several methods of procedure in deter-

mining the average widths and average values of these blocks may be used; of these methods, only two will be mentioned:

1. Any one of these blocks of probable ore may be assigned an average width and average value equal to an average of the figures for the blocks of proved ore above and below it.

2. All the blocks of probable ore may be assigned an average width and average value equal to an average of the figures for all the blocks of proved ore in the mine. In most cases, this would seem to be the simplest method—unless geologic evidence indicates that some other method should be used—but it is not logically exact and in some cases it may be a dangerous assumption. It is worth pointing out, however, that the risk of assuming continuity of value in all the areas blocked out as probable ore is by no means the same in all parts of that area. Block 11, for example, surrounded on three sides by blocks of proved ore, is much more likely to possess an average width and average value close to the averages for proved ore than are blocks 12 and 15. It is reasonable to expect a wide variation within the boundaries of a single block; ore value in block 12 might reasonably be much more certain of continuity at point A than at point B, which latter is 590 feet from the nearest sampled opening. Since we assume that no signs have been encountered to indicate that block 12 does not lie in the vein, however, it has in this case been classified as probable ore.

Using the second of the methods just described, it will now be possible to calculate the averages and total tonnage of all the probable ore in the mine, as shown in blocks 11–15.

EXAMPLE 6

The measured dimensions of blocks 11–15 of probable ore are given in Table 6 below. The total area covered by these blocks may

TABLE 6

AREA OF FIVE BLOCKS OF PROBABLE ORE IN A MINE

Block	Length in Feet	Height in Feet	Length × Height in Feet
11	320	200	*64,000*
12	510	490	*249,900*
13	90	190	*17,100*
14	90	90	*8,100*
15	330	290	*95,700*
Sum			*434,800*

be calculated, multiplied by the average width (assumed to be equal to that found in Example 5 for proved ore), and the total volume resulting may then be converted into tons and multiplied by the average value (assumed to be equal to that found for proved ore) to obtain the total tonnage and value of all probable ore in the mine.

Reducing the method here used to a formula:

$$\frac{\text{Area of probable ore blocks} \times \text{average width of proved ore}}{\text{Number of cubic feet of ore in one ton of proved ore}} = \text{tonnage of probable ore}$$

Using the sum computed from Table 6:

$$\frac{434{,}800 \text{ sq. ft.} \times 6.17 \text{ ft.}}{15} = 178{,}848 \pm \textit{tons of probable ore}$$

The probable ore in the mine is therefore found to be 178,848 tons, to which is arbitrarily assigned in this example an average value of $9.64, the average value of the proved ore. In many cases there will be evidence for assuming a lower, or sometimes a higher, value, depending on the values of the various ore shoots in certain levels and their pitch; the use of such evidence must be left to the judgment of the engineer. Other ways of approaching this problem may be found, but this method is adequate to show the difficulties to be met and to give at least one rational method of approach to the problem.

Ore reserves.—The ore reserves of a mine will be stated as the total tonnage and average value of proved ore, plus the total tonnage and value (assumed) of the probable ore. Careful determination of ore reserves will give a reliable statement of the revenue which may be expected to form the foundation upon which may be erected a financial program for operating the mine.

EXAMPLE 7

The ore reserves of the mine under examination are stated in Table 7.

This total tonnage of ore may be checked by calculating the total volume of the blocks classed as ore reserves and dividing by the number of cubic feet of ore in one ton. Then:

$$\frac{1{,}390 \text{ ft.} \times 880 \text{ ft.} \times 6.17 \text{ ft.}}{15} = \textit{503,143 tons}$$

which checks the tonnage of the ore reserves closely.

TABLE 7

STATEMENT OF ORE RESERVES

	Tons	Average Width	Average Value
Proved ore	324,357	6.17	$9.64
Probable ore	178,848	6.17*	9.64*
Ore reserves	*503,205*—say *500,000 tons*		

* Assumed from Table 5.

It may be observed that there is a slight discrepancy between the vertical depth of the mine and the depth measured on the dip of the vein, which is not vertical but, as shown by the cross-section view of Figure 4, dips perceptibly, so that the distance on the vein between vertical levels of 100 feet may be as much as 110 feet. This discrepancy is partly compensated for by the fact that some 7 feet of the vein have been removed by development work, so that the ore taken out is not included in the ore reserves at the time of examination. The net result of the discrepancy here noted would be the inclusion of a hidden factor of safety in the estimated reserves; this factor is rather small, however, and would have no effect on the validity of the final result. If the dip of the vein is much off the vertical, all measurements for quantity should be made on the dip.

The statement of the ore reserves shows the total tonnage and average value per ton which comprise the whole source of the maximal revenue that the engineer is justified in expecting will be derived from extracting the ore. This sum, however, is subject to a series of deductions representing margin of safety, adjustment of assay value, losses in treatment, costs of operation, and city office expense, as well as the charges representing the financial risk of the undertaking. These items of loss and expenditure will be discussed in subsequent chapters, and the present example will be fully worked out in chapter 8, in which place the present value of the mine under consideration will be calculated on 500,000 tons of proved and probable ore of a value of $9.64 per ton, or a gross value of $4,820,000.

Prospective ore.—In the hypothetical example here given, all ore conjectured to lie within the vertical boundaries blocked out in the sketch and below the attained depth of 890 feet should be classified as prospective ore. No tonnage or value figures can be stated for this portion, nor can this ore be included in any estimate of ore

reserves. Since the mine has shown no sign of bottoming, there may be a certain amount of ore below the lower boundary; but no financial program should be based upon its possible recovery.

ESTIMATING RESERVES FROM INCOMPLETE DATA

Frequently the engineer will be called upon to make a valuation of prospects or other types of property where any sampling that can be done will yield no conclusive evidence upon which to base estimates of tonnage and value. In such cases he must cheerfully undertake to present a report attempting to reach a reliable conclusion, considering the full possibilities of the small array of facts he can obtain, since it is often true that limitations of time and money make extended examination or development impracticable.

It may be confidently asserted that some conclusion can be reached in most cases of slightly developed properties by painstaking and detailed study of such evidence as exists. A small residuum of properties that cannot be valued by any means short of crystal-gazing will remain. The Scotch verdict of "not proven" is an unhappy episode in the life of every engineer. However, since he has been employed to give an opinion, his best policy is to discuss the situation fully in his report, give all his reasons for failing to reach a conclusion, and, if possible, give a definite opinion that will not leave his client in doubt. He should avoid putting himself behind such a maze of words that his client has to ask him, as once happened: "Is this a rich mine, or a swindle?" Of course, much depends on the character of the client for whom the report is made. One large mine operator says that he does not want prophecies; he wants facts, and can make predictions as well as the next man. It was reported, on the other hand, that a heavy speculator in mines once told his young engineer: "I don't care if you get me into a poor mine, but God forgive you if you turn down a good mine, for I never will."

Good mines, as has been said, are very rare, and it would be unfortunate if a good one were missed through the engineer's timidity. Some of the most prominent engineers, although they have made many errors of judgment based on meager data, still retain the confidence of their clients, for one success may more than counterbalance several failures.

Prospects.—The most lucrative field of mining is the development of a successful prospect. For this reason operators are continually

investigating prospects, and many cases of valuation deal with mines having little or no development work, so that the values are wholly speculative. Such enterprises generally result in the loss of the entire investment. Where no ore reserves may be stated, the prospective returns must be more than large enough to justify the expenditure of any money involved. Since the development of prospects is so highly speculative—not one prospect in five hundred realizing the hopes held for it by the possessor—engineers are naturally loath to advise their acquisition. This risk of developing a prospect, however, may be justified if it is assumed with full understanding of the limitations, and these should be stated in the engineer's report. Usually the best policy in such a situation is to take an option to buy the property after a period long enough to permit the purchaser to perform sufficient development work to come to a reasoned decision.

Although some prospects that the engineer will be called upon to evaluate may show a few tons of proved ore, and a somewhat larger tonnage of probable ore, the chief attraction of a prospect lies in the geologic and mineralogic potentialities of prospective ore, which cannot be directly sampled or measured. However, in many cases it is quite possible to say that the bargain is likely to prove a good one, despite the impossibility of placing even an approximate value on the property. A great proportion of prospects may be immediately condemned as not worth the large price asked, while occasionally the engineer will feel justified in reporting that the prospect is worthy of further investigation and development. In the latter instance, the ability of the engineer as a negotiator will be tested; for he may have to deal with a prospector with an exaggerated conception of the price he should receive for his hole in the ground.

The prospector is an important member of the mining fraternity whose rewards for his discoveries are as a rule but scanty and who deserves the respect of all engineers. But he is often a difficult person to deal with, especially if he believes that the engineer represents important capitalists; and it is frequently hard to induce him to close a deal at a reasonable price. Tactful negotiations may, however, convince him that the engineer's client is in earnest, that he is financially sound, and that the property cannot be favorably recommended unless time for examination or development is available. Such a frank statement has often led to an option with time for further development, and many valuable mines have been thus acquired.

Virgin prospects which are virtually undeveloped are seldom pur-

chased upon the recommendations in an engineer's report. This field of promotion is more suited to individual operators than to mining companies. Probably no living engineer would recommend that his clients follow the example of a 'forty-niner and cattleman who later became a mine operator.[4] This man was a large shareholder in a mine at Tuscarora, Nevada; while visiting this property he passed through the assay office and noticed some large buttons of silver on the cupels and was told that the samples came from a prospect hole that had been started a week or so before. Mounting his horse, he rode over to the prospect and found a small hole with a vein of rich silver ore. Possibly an engineer might have bought out the prospector for a few thousand dollars and then worried lest he had paid too much; but this man paid the prospector his asking price. No sooner had he bought out the prospector than a second man came along and stated that the claim belonged to him. The operator likewise bought him out, and satisfied the demands of several other claimants. Before he left the site of the hole he had paid out $85,000. His faith was vindicated, for the prospect developed into one of the largest dividend-payers in that rich camp; but no engineer would have been justified in recommending the payment of $85,000 on such a showing. To do so would be to make a guess that at least $350,000 in profit would come out of the prospect.

Mines with little ore showing.—Aside from prospects, there often arises a need for the valuation of mines where development has revealed little ore but where there is some likelihood of its existence. Such an instance would be the valuation of a property adjoining a developed deposit with probable longitudinal extension; no ore upon which to base an opinion would be visible in the property under consideration. Again, in regions where claims are limited by vertical sidelines, there is the possibility of encountering a "deep level" in inclined deposits. Therefore the area surrounding known deposits has a certain speculative value upon which engineers may be called upon to pass judgment. Except in uniform and extensive deposits—such, for example, as the South African "bankets" or the Lake Superior copper region—exploring for deep level extension is generally a highly speculative phase of mining.

Equally hazardous is the valuation of a mine that has made great profits from small pockets of very rich ore, without any large amount

[4] Shockley, W. H., and Cranston, R. E., "The Organization of Mining Companies," *Trans. International Engineering Congress*, San Francisco, 1915.

of ore showing at any one time. Such mines, although they have no ore showing at the time of examination, may prove very valuable in the future, but valuation of them is a trying task to engineers who depend only upon evidences of extension. The difficulty of valuing a mine of this type is described by Mark R. Lamb.[5] The Batopilas mines were under examination, and Governor Shepherd, who was in charge of the mine, questioned the examining engineer to discover why he was sampling rock that was obviously barren. Upon being told that it was to determine how much ore was in sight, he said: "We have *no* ore in sight. Just as soon as it gets in sight we take it out of sight." It is said that this engineer reported the mine to have ore in sight worth about one-tenth of the price asked; but in the short time between the examination and the publication of the engineer's report the mine produced more metal than he had reported to be in sight.

This mine, like many others, is chronically out of ore; but when a pocket is discovered it yields almost pure silver. Daily shipments from the mine have at times closely approached $100,000. At one time the Governor unexpectedly drew a draft on the mine for $90,000. No ore was in sight until 6:00 P.M. on the last day of grace, when thirty mule-loads of silver were discovered and taken out. This ore was "in sight" less than forty-eight hours. The only way to evaluate such a mine is to examine the books. It is well in this connection, however, to remember R. W. Raymond's phrase: "The record of past production is a measure, not of what is left, but of what is not left, in the ore deposit of a mine."[6]

Erratic orebodies.—The danger of estimating the extent of ore deposits even with the aid of abundant knowledge of mining geology is brought out in the discussion of the paper by J. D. Kendall already cited.[7] This article is worthy of careful study and may be considered as a critique of the science of estimating ore.

One example of the disappointing results of attempting to determine ore reserves is given by Dr. A. L. Simon,[8] who had been asked at one time to fix upon the quantity of ore in a large Russian

[5] Lamb, Mark R., "Stories of the Batopilas Mines, Chihuahua," *Engin. Min. Jour.*, April 4, 1908, pp. 689–91.

[6] Raymond, R. W., "Ancient History and Modern Investment," *Engin. Min. Jour.*, March 10, 1906, pp. 457–58.

[7] Kendall, J. D., "Ore in Sight," *Trans. Inst. Min. & Met.*, London, Vol. 10 (1901–1902), pp. 143–202.

[8] *Ibid.*, pp. 173–74.

property that had been previously assumed to contain about 500,000 tons. He could find only some 2,700 tons, however; the earlier estimate had been based largely on extravagant assumptions. The fact was that the property possessed some twenty-seven reefs, lying more or less parallel through an area measuring about three miles in length and one mile in width. For the whole length of the reefs one could see the workings. The reefs were being worked to a depth of about one hundred feet, and the company assumed that they would be able to attack the same reefs at a deeper level by putting a general crosscut through the country about three-quarters of a mile in length, tapping all the veins which apparently would be cut by it. As a matter of fact, the veins vanished at about 150 feet in depth, as far as payable gold content was concerned, and could not be worked profitably below that depth.

Another mine operator[9] related that he had found from his own bitter experience that to estimate any high values at depths greater than one could see and sample was remarkably dangerous, and to illustrate his point mentioned the Drum Lummon mine in Montana. That mine had been opened for a depth of 400 feet; on the 400-foot level it had been developed longitudinally for about 3,000 feet, and in that length they had ore shoots aggregating not less than 1,500 feet. They averaged about ten feet in width, and from $40 to $50 per ton. When that level was opened up, he thought they had the biggest mine in the world, and at that time he would have said that anybody making an examination for purchase might have been justified in assuming a great deal below that depth. When they reached the 500-foot level, at the point where the crosscut first touched the lode, it sampled about $20 per ton. They thought this merely a local impoverishment, and paid small attention to it. At the 800-foot level it was worth nothing, and subsequent developments proved that those large orebodies, which had been uniformly rich from the surface, were, at 25 feet below the 500-foot level, of practically no value. With that illustration in mind it would probably not be thought unreasonable for the engineer to be especially cautious in giving a mine credit for anything more than he could see.

Similar experiences of the erratic nature of certain orebodies can be related by most mining engineers; and although such conditions may be exceptional they indicate that caution must be used in assuming the continuity of values with depth, even when the showing in the upper levels is consistently satisfactory.

[9] Kendall, J. D., *op. cit.*

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Chapter 7

Recoverable Value and Cost of Mining

The maximal revenue that may be expected from the exploitation of the mine is subject, as stated at the end of chapter 2, to a series of deductions representing dilution, margin of engineering safety, losses in treatment, and costs of production, in order to arrive at the profit that may be won from the venture.

RECOVERABLE VALUE

Adjustment of assay value.—A very important matter is the decision as to the proper deduction that should be made to adjust the estimates based on sampling and assaying. Allowance should be made for dilution, and a margin should be extended to cover the errors of sampling.

Experience shows that it is ordinarily impossible to mine a block of ore without breaking out a certain amount of barren wall rock which dilutes the ore and thus reduces its value per ton. In some mines, such as those with a decomposed or shattered hanging wall, this dilution factor may be large.

It has also proved true that ore when worked seldom shows the actual return estimated by sampling; this error has already been mentioned above on page 67. It is almost invariably true that the recovered metal product, plus all the known losses in unsalable waste (tailing, slag, dust, and fume), does not equal in gross value the estimates from the most careful hand sampling. Hence, a correction of the sampled value must be made. The proper amount of this correction—that is, the deduction—is best determined by actual working of large sample lots of ore, when this course is practicable, as explained in discussing the "combination method" of sampling, on page 67. If this method of large-scale checks cannot be employed, the percentage of deduction must be adduced from experience with similar ore. In default of such a comparison it is advisable to deduct at least 10 per cent of the assay value as a factor of engineering safety to cover dilution and error in sampling.

Percentage of recovery.—No method of mining, milling, or treating ore will return the full quantity of metal present. Losses of greater or less degree occur during each process, and although it is frequently difficult to determine such losses beforehand, it is safe to say that they are more often underestimated than the reverse. Mining and metallurgical science has advanced to a point where the proportion of metal product that is lost or discarded is dependent principally upon the economic factor of price; when the cost of cutting down losses is greater than the value of the extra metal recovered, it is obviously not to the advantage of the operators to attempt such expensive reduction in losses.

The percentage of recovery to be expected from the various methods of mining and treatment may be determined from actual mill tests or from records and metallurgical experience, and varies from 33 to 98 per cent for different metals and processes. Finlay[1] gives the following percentages of recovery in 100-ton lots of ore for some important metal districts in this country:

Cripple Creek gold	78 to 94 per cent
Lake Superior copper	64 per cent
S.E. Missouri lead	58 to 72 per cent
S.W. Missouri zinc	33 to 52 per cent

These percentages seem low in view of the results obtainable by the application of flotation processes, and are probably somewhat less than would be recovered by modern practice.

A knowledge of the percentage of recovery is as important as a knowledge of the gross value of the ore. The optimal percentage is usually a function of operating cost. One hundred per cent recovery could be obtained from almost every ore, but never profitably. Copper ore may be smelted and 90 per cent or more of the metal extracted. The same ore, if concentrated before smelting, might yield a profit at 70 per cent recovery; the additional 20 per cent which might be obtained by roasting and leaching the residue would probably result in an expenditure far greater than its value. The application of flotation processes would considerably increase these percentages, but would not give complete recovery.

Under normal conditions a recovery of 85 to 95 per cent from a gold-silver quartz ore may be expected; and a recovery of 75 to 95 per cent from a concentrating base-metal ore may be advisable,

[1] Finlay, J. R., *The Cost of Mining*, 3d ed., p. 55.

depending on the nature of the ore, the stipulations of smelter contracts, and the prevailing price of the metal.

Consideration of the needs of the race for large supplies of metals and mineral products requires that any advance in metallurgical science or mine management that will decrease the amounts of valuable metal annually wasted during treatment should be adopted whenever commercially possible.

THE COST OF MINING

The estimation of costs of mining is a difficult task and the one on which the valuing engineer is most likely to err. The reasons for this are apparent: costs vary considerably for each mine, and indeed for each kind and type of ore through all extraction and treatment processes; it is often impossible to obtain accurate cost figures even from the records of a mine that has been operating for some time; and the general complexity of the subject makes the opportunity for error very great.

Costs are ordinarily divided into "capital expenditure" and "operating cost." In the words of Finlay:

> Operating, or current operating, charges are those that relate to the obtaining of product. It includes all the labor, salaries, and supplies used on the actual yield of a mine for a limited period, but excludes all charges that may be a preparation for a yield to be obtained later. Note that I say "for a limited period"; for I make it a cardinal and self-evident axiom that whenever we extend our point of view to the whole life of a mine or property, we immediately abolish the difference between operating and capital costs. Then *all* expenses are operating expenses.[2]

The correct handling of capital and operating charges is beset with difficulties even when there is no intent to offer a misleading report by charging as capital assets what are really operating expenses. Further discussion of this involved question as it relates to accounting methods will be deferred to a later chapter.

The three items of cost that call for an initial outlay of capital are those for purchase of property, for preliminary underground development, and for purchase of plant and equipment. All other disbursements may be properly termed "operating cost"; and the costs of mining may be listed thus:

Capital Expenditure
- Purchase price
- Preliminary development
- Cost of plant and equipment

[2] Finlay, J. R., *The Cost of Mining*, 3d ed., McGraw-Hill, p. 63.

Operating Cost	
Development	Labor, Supplies, Power
Stoping	
Transportation	
Treatment	
Administration at mine	
Maintenance	
City office expense	

OPERATING COST

Operating cost will be considered in this section as an estimate for the purpose of valuing a property.

Before passing to a survey of some of the commonest factors of operating cost in mine valuation, a few general considerations must be taken into account.

Margin of safety.—Chief among these considerations is the tendency to underestimate costs. It may be stated without qualification that the general propensity of valuing engineers is to underrate the costs of operation. A wide personal experience and a still wider association with engineers concerned with mine finance have not revealed a single instance in which the costs of mining and milling were overestimated.

It is clear that the engineer should not hesitate to add a reasonable factor of safety to any figures estimated as the probable working cost of a mine under his consideration, especially an undeveloped mine or one in a newly opened district where long-term records are not available.

Possible reduction of costs.—Even when a mine is in operation, one is sometimes tempted to dream that conditions in the future will improve through the application of different methods of mining and treatment, or through more efficient management. If the engineer knew at the time he indulged in such sanguine estimates that he would be responsible for the successful establishment of such "money-saving" schemes, he would often be speedily deterred from including such possibilities in his valuation.

The introduction of untried methods, as previously mentioned, seldom effects any great saving, and may indeed cause disastrous losses. As a rule the methods employed in any established mining district are those that have proved to be best adapted to it, and it

is extremely unlikely that costs will be drastically reduced by a change of mining or metallurgical methods.[3]

One reason that the methods in use are probably the best available is that operating engineers these days are an alert and well-informed group, not likely to overlook any new developments in mining or metallurgy.

In these days of reconstruction after two wars, a safety factor of 50 per cent to 100 per cent should be added. How long this period of uncertainty will last no one knows.

But under exceptional circumstances a valuing engineer may be in a position to perceive where changes might be introduced that would diminish cost of operation. A delicate ethical problem is here introduced: should the existing mine management be informed of such possible methods of improvement? If negotiations for the purchase of the property are still in progress, it is plainly the duty of the engineer to confine his discovery to an explanation to his client. But if the engineer becomes eventually certain that his present client will not purchase the property, he would serve public interest by pointing out to the mine management that certain changes could be made to reduce existing cost of production. One method of cutting cost which should not be overlooked is the consolidation of several mines under the same management.

Low costs not always economical.—It may be well to consider Finlay's observation that efforts to lower costs have in many cases resulted in good mines being run at a loss. Quoting the example given by him:

> Let us take as a practical example a body of 10,000 tons of ore, running one ounce gold per ton. This ore can be shipped without sorting at a handsome profit, as follows:

Gross value of ore		$200,000
Cost of mining 10,000 tons at $3 per ton	$30,000	
Freight and treatment at $8.25	82,500	112,500
Profit		$ 87,500

> But suppose that we reject half this ore by sorting. By so doing we throw away 5,000 tons that will average $2.50 per ton, or $12,500.

5,000 tons at $37.50 per ton		$187,500
Freight and treatment at $11.25 per ton	$56,250	
Cost of mining and sorting	32,500	88,750
Profit		$ 98,750

[3] See Finlay, J. R., *The Cost of Mining*, 3d ed., pp. 57–59.

In other words, the gross receipts in this case have fallen $12,500; the cost of mining per ton is more than twice as great; the cost for freight and treatment is $3 per ton greater. The apparent showing by the superintendent is very bad; but, nevertheless, he has made for the company $11,250 clear profit on the transaction.

In the first case our total cost of mining, freight, and treatment is only $11.25 per ton; in the second case it is $17.75 per ton, but there is more money in the higher cost. It is an example that has been worked out in practice.

A false economy often results from mining too much in a mere attempt to produce a greater output than the development of the mine really warrants. This invariably results in mining waste at a dead loss, but as this loss is on the same basis as the above, there seems no need to follow the discussion further.[4]

Unit of cost.—The unit of cost estimates, in most cases, will be cost per ton of ore; but not infrequently—especially in the case of copper—the figures may be reduced to the cost per pound of metal produced. The cost per unit of product is especially useful in valuation for expressing directly the profit or loss to be expected from working blocks of low-grade material. A client will not hesitate, for example, to agree with the engineer's estimate that a certain block of gold-bearing rock is not worth mining if the figures demonstrate that each ounce of the metal will cost at least $20.67 to obtain.

Types of operating costs.—The operating costs of mining may logically be divided into two types: (1) expenses that vary with the quantity handled, such as cost of stoping, supplies, and ore treatment; and (2) expenses independent of tonnage which may be termed "fixed charges," or "overhead." Pumping charges, salaries for superintendence, and many incidental expenses are of this latter type.

The types of cost may be listed in more detail as follows:

1. Expenses dependent on tonnage treated: (*a*) direct functions of tonnage, as stoping and tramming; (*b*) indirect functions of tonnage, as development and repairs.

2. Expenses independent of tonnage treated: (*a*) constant, such as superintendence; (*b*) variable, such as traveling expenses or other expenses which may vary with the season.

Such classifications have considerable theoretical interest, and an analysis on this basis tends to clarify the origins of expenses, but the engineer will find a complete list of factors influencing cost of mining to be of more practical use if due attention is given separately to each item.

[4] Finlay, *op. cit.*, pp. 52–53.

SOME FACTORS AFFECTING OPERATING COST

The list of factors in valuation given in chapter 2 may all be considered, in some part at least, to affect the cost of mining a given ore deposit. Some comment is here made on the more important of these factors, in their direct bearing upon operating cost.

City office expense.—A heavy burden upon operating cost will be imposed by expenses for central administration, as distinguished from administration at the mine or treatment plant. These expenses include such items as city office rent, staff, directors' fees, legal and technical advice, tax on profits, bond or debenture interest and redemption, royalties, traveling and incidental expenses, damages, and a vast number of miscellaneous small charges.

These expenditures are truly an operating cost, since they must be deducted from the operating profit of the business before dividends are paid. Their exact amount, however, is usually unknown to the examining engineer; but it is almost always large, and for his purpose may be handled by boldly deducting 20 to 33 per cent from the operating profit.

The magnitude of this expense is shown by a comparison of operating profits from mine and treatment plant with the amount paid in dividends, taken from the reports of representative mines in various parts of the world:[5]

ENTIRE RAND GOLD FIELD

	1915	1914	1913
Operating profit	$59,655,000	$57,768,000	$60,946,000
Dividends declared	38,097,000	40,367,000	40,970,000
Percentage paid as dividends	63.9	69.9	67.2

FOUR OF THE LARGEST GOLD MINES IN RHODESIA

	Year A	Year B
Operating profit	$3,537,000	$3,464,000
Dividends paid	2,315,000	2,519,000
Percentage paid as dividends..............	65.4	72.7

THREE LARGE PORPHYRY COPPER MINES IN THE UNITED STATES

	1915	1914	1913
Net operating profit plus income..	$29,588,000	$14,640,000	$14,776,000
Dividends paid	11,386,000	8,086,000	8,298,000
Percentage paid as dividends..	38.4	55.2	56.1

[5] Pickering, J. C., *Engineering Analysis of a Mining Share*, p. 44.

Two Gold Mines on Douglas Island, Alaska

	1915	1914	1913
Operating profit	$1,063,000	$1,644,000	$1,681,000
Dividends paid	902,000	1,262,000	1,414,000
Percentage paid as dividends...	84.8	76.7	84.1

The difference between operating profit and amount paid as dividends is, it may be assumed, swallowed up by the various expenses of central administration. The student can thus see that the 20 per cent suggested as a deduction from operating profit to cover city office expense is none too large.

Size of deposit.—The size of the deposit exerts a powerful influence on the costs of operation. Those mining operations that can be carried on with large tonnages are accompanied by the lowest costs. This is because the overhead expenses are divided by a large tonnage; also, the principles governing mass production here obtain; moreover, the application of mechanical devices is much more effective for large tonnages than for small. The conditions under which a small mine will be profitable have been described by Young.[6]

Width of vein.—A miner can work in stopes as narrow as twenty-eight inches if the supporting walls are sufficiently strong and if the vein is rich enough to pay the expense entailed. If the vein is much narrower than this, greater allowance must be made for dilution of ore taken out. If, for example, the vein be only a foot wide and it is necessary to mine a foot or two of barren rock in order to get out the ore, the average value of the material stoped will be reduced to one-half or one-third the value of the sample from the vein.

The benefit that may be derived from underground sorting of ore must also be considered. Careful selection of profitable material may greatly reduce costs of handling and treatment.

Hardness of ore: supporting walls.—The hardness of the ore is relatively unimportant, affecting merely one division of underground work; that is, the breaking of the rock. The instability of the supporting walls is likely to be a much greater source of expense, requiring in some cases a considerable outlay for timber, which may have to be brought from a great distance. Some mines require as much as fifty feet of timber per ton of ore mined, and if such a quantity costs $5, it is evident that the grade of the ore must be high if the operations are to be profitable.

[6] Young, George J., "When the Small Mine Pays," *Engin. Min. Jour.*, July 7, 1928, pp. 8–10.

Unstable walls also increase working costs because of the amount of labor involved in continually renewing timbering and in removing fallen and caved material from drifts and crosscuts. There is also the constant menace to life, as well as losses resulting from failure to maintain the workings in open and safe condition.

Increase of cost with depth.—It may be well to repeat that the mining of a deposit at certain depths will be prohibitive if the cost of extracting the material at that depth is greater than its market value. As stated in chapter 5, few mines—apart from those of precious metals and tin—operate profitably at depths greater than 2,000 feet. Most of the mines of the world shut down before they attain a depth of 500 feet; a relatively small number attain 1,000 feet; a few operate successfully at 2,000 feet; but it is doubtful if there are twenty mines in the world now conducting operations at depths in excess of 5,000 feet. Direct operating cost is of course not the sole reason for failure to exploit a deposit to considerable depth: a mine is frequently abandoned because the vein pinches out, or becomes so low in value that it would not pay under any conditions. But many mines shutting down at shallow depths are abandoned because working costs have been increased to a point at which the ore will not repay expenses, or because the ore is not sufficiently consistent and extensive to justify the expenditure of capital for deep-mining equipment.

The temperature of underground workings increases, as indicated in chapter 2, in no regular manner; but when it does increase beyond about 70° F. the cost of underground operations will begin to rise materially. Above this temperature the atmosphere becomes progressively so enervating that men cannot perform a full shift of normal labor. That temperature does not increase in proportion to depth attained, however, is shown in the working of several large sulphide-ore deposits wherein the first three or four hundred feet from the surface are subjected to slight oxidation that will cause temperatures as high as 100° or 110°, while on levels below these, where oxidation has not taken place, the working temperature may be quite comfortable.

Inclination of vein.—A large body of ore lying in a vertical, or nearly vertical, position can seldom be mined as cheaply as one of the same size lying at a relatively slight inclination near the surface. This fact is illustrated in the coal seams of New York and Pennsylvania, which can be developed by tunnels rather than vertical shafts.

If the method of mining involves support by filling, the inclined vein is obviously less expensive, because the filling rests upon the foot wall and supports the hanging wall; whereas if the vein is vertical, the increasing quantity of filling will tend to settle on the lowest supports.

Point of entry.—If sufficient development work to ascertain the plane and extent of the deposit has not been done, the main shaft may be located at a point that will not be close enough to the center of operations, and much costly underground tramming might be necessary. This would entail great expense for underground handling, and the necessary construction of a second shaft would place a further burden upon the capital funds for development and equipment.

The relative merits of inclined and vertical shafts in the exploitation of metal deposits have been summarized by John Malcolm Nicol,[7] and are shown to depend upon the particular type of deposit to be worked.

Hoisting.—The costs of hoisting increase with depth, but not proportionately to depth. The same general equipment must be provided to operate a mine at 1,000 feet as at 200 feet; but as depth becomes greater, the loss of time in transporting men and ore will add slightly to operating cost. The value of the miner's time when he might be at work must also be included if the mine management considers, as is usual, that a shift begins and ends at the collar of a shaft.

Homogeneity of ore.—It is easy to see that a lode that is payable throughout can be more easily and cheaply exploited than one in which the proportion of metal content to gangue varies widely at different points. In the latter case, much more development and exploration will be needed in order to develop the payable ore; whereas, if the grade of the ore is relatively constant, all blocks that are developed can be extracted *in toto* and subjected to identical treatment.

Extreme variability occurs in some of the silver mines of Mexico where the gangue is quartz and the payable mineral is stephanite. In one of these mines in the state of Durango, this silver mineral occurs in masses varying in size from that of a pea to those weighing tons. This mine has a long history of profitable operation, but there have been many occasions when the engineer in charge had no

[7] Nicol, J. M., "Vertical vs. Incline Shafts in Metal Mining," *Min. & Engin. World*, March 30, 1912, pp. 701–702.

idea where he would find sufficient ore to run through his mill on the following day. At other times he would have several millions of dollars worth of high-grade ore blocked out. Hundreds of feet of barren quartz might be driven through before a body of stephanite —perhaps a few hundred pounds, perhaps tons—would be struck. The profits from these occasional masses of ore must, of course, bear the expense of this extensive development work.

Type of metal.—Justifiable costs of production will vary greatly over the whole range of metals, depending on the availability of the product and on the demand for it. Maximal working costs may be allowable from a few cents a pound for zinc and lead to approximately $150 per pound for gold, and even higher for the rare elements.

Method of mining.—Operating cost will in large part be determined by the method selected for extracting the ore. The choice of method depends upon whether the nature, position, and extent of the ore deposit lends itself to exploitation by open-cast, steam-shovel, dredging, hydraulic, or underground stoping methods. Factors to be considered are the physical characteristics of the deposit and the inclosing rock, the grade and distribution of the valuable minerals contained therein, and the resources of the operating company. The most economical method will be that which is most efficient and safe, for improper methods may result in high costs, low extraction, and endangerment of life.

The cheapest means of handling large masses of material is by the use of water under great pressure, as commonly employed in hydraulic mining. The minimum cost of this work was probably attained at North Bloomfield, California, in the 'seventies, when many thousands of cubic yards of top dirt were handled for slightly less than three cents a yard.[8] Under ordinary conditions, however, the cost of hydraulicking should not be estimated at less than 5 to 10 cents a cubic yard.

Dredging costs, under normally favorable conditions, commonly run to a similar figure. Although California gold dredges have operated over long periods for much less than 5 cents a cubic yard, and large modern tin dredges for about that figure, such a cost is generally exceeded greatly, even by well-managed companies.

Next in cheapness to placer manipulation is the use of steam-

[8] Peele, Robert (ed.), *Mining Engineers' Handbook*, 2d ed., p. 906.

shovel methods in open-cut mining. The cost of this work at the Nevada Consolidated Copper Company during the years 1921–24 varied from 20 to 28 cents per ton of ore and from 41 to 50 cents per cubic yard of stripping removed. The cost of stripping in this case is somewhat higher than usual under typical conditions.

A valuable discussion of comparative advantages and costs of the various methods of mining will be found in *U.S. Bureau of Mines Information Circular 6503,* 1931, "Mining Methods and Costs at Metal Mines of the United States," by Charles Will Wright, from which the table on the opposite page is reprinted.

TABLE 8

AVERAGE RESULTS FOR DIFFERENT MINING METHODS

Mining Method	Man-Hours per Ton, All Under-ground Labor	Tons per Man-Shift, All Under-ground Labor	Explosives Used per Ton, Pounds	Power, kw. h. per Ton	Total Under-ground Cost per Ton
Square-set	5.15	1.553	1.363	34.9	$4.825
Average of	61 mines	61 mines	10 mines	19 mines	11 mines
Cut-and-fill	4.34	1.843	.660	10.045	$3.076
Average of	21 mines	21 mines	5 mines	4 mines	5 mines
Shrinkage	1.33	6.015	1.656	15.33	$2.682
Average of	37 mines	37 mines	18 mines	16 mines	16 mines
Open-stope	1.17	6.837	.844	8.90	$1.250
Average of	170 mines	170 mines	22 mines	17 mines	19 mines
Sub-level caving	.95	8.421	.605	13.00	$1.438
Average of	17 mines	17 mines	4 mines	2 mines	2 mines
Top slicing	.932	8.584	.520	7.252	$1.208
Average of	37 mines	37 mines	13 mines	12 mines	3 mines
Caving	.628	12.739	.244	3.0	.516
Average of	7 mines	7 mines	3 mines	3 mines	4 mines
Open-cut (surface)	.324	24.691	.308	2.71	.309
Average of	55 mines	55 mines	3 mines	3 mines	3 mines

Method of development.—Adequate development work, particularly to determine the depth and lateral limits of the deposit, although it may initially make serious demands on capital, is an essential operation if extraction of ore is to go forward steadily and efficiently. Advance development work is especially needed if the distribution of ore is uneven or if the deposit has an eccentric shape, and in such case the expense of preliminary development work might be properly considered as an item of capital expenditure rather than of operating

cost. No sound financial program for the exploitation of an orebody can be laid out until extensive exploratory openings have been run. If the deposit is suited to diamond-drilling, fewer large openings will be required.

The method of development used, and its cost, will depend on the mining method selected. Adequate development work to determine the nature and refractoriness of the ore should of course precede any commitment for design or construction of metallurgical equipment.

Method of treatment.—The greatest operating profits will be made if the most economical treatment process for each particular kind of ore is determined previous to installation, so that the optimal percentage of profitable recovery will be obtained. By the adoption of modern processes such as flotation and cyanidation many losing ventures have been transformed into profitable mines.

The simple gold ores, like those of California, are put through the simplest of all metallurgical devices—a stamp mill (or some form of ball mill), whereby the ore is pulverized and the gold extracted by amalgamation with quicksilver. Some attempt to recover a few cents' worth per ton in valuable iron-pyrite concentrates may follow, but this will have little effect on operating expense as a whole. This example presents a metallurgical treatment of extreme simplicity and low cost.

At the other extreme of complexity one might consider ores from the Harz Mountains in Germany, deposits that have been worked for hundreds of years. The operations attained a depth considerably below the zone of oxidation, and the minerals were sulphides of iron, zinc, copper, and lead, each of which contained traces of gold and silver. When the ore was hoisted to the surface the first operation was to eliminate a portion of the worthless gangue by hand sorting. The selected ore was then sent to the concentrating mill, where it was first subjected to jigging, which yielded coarse lead concentrates. After a long series of recrushing and reconcentrating operations by means of gravity machines, magnetic machines, and flotation processes, three classes of concentrates—copper, zinc, and lead—were finally produced. These concentrates were then sent to smelters, where the metals were separated by smelting methods suitable for each. The silver and gold were found indiscriminately in each type of concentrate, and the copper, zinc, and lead recovered were therefore put through refining processes to recover the precious metals. Finally the gold and silver were put through a metallurgical

process that would separate them. As each atom of metal went through many operations before it finally appeared in a form suitable for realization, costs were tremendously high. A mine could not be operated under these conditions unless the ore was extremely rich, or unless, as in this case, the mines were subsidized by the government and maintained as an educational institution for the training of mining and metallurgical engineers.

Another example of costly treatment was the copper-gold deposit at Rossland, British Columbia. This ore contained 3 per cent copper, and $3 per ton of gold. The objectionable feature of the Rossland ore was that the gold accompanied or was associated with the copper minerals. Concentration processes as at that time known served to recover only a part of the copper and part of the gold contents; in order to obtain complete gold extraction all the ore had therefore to be smelted and thus subjected to a relatively expensive metallurgical treatment.

A further instance of the effect of metallurgical difficulties upon cost may be given by comparing the zinc deposits of Missouri with the zinc deposits of Broken Hill, New South Wales. The typical Missouri formation is a limestone carrying zinc sulphide and lead sulphide, but the two sulphides are so coarsely crystalline that they are quite readily separated by water-gravity concentration, and, more recently, flotation. This water concentration gives very pure concentrates; that is, the zinc concentrate contains very little lead, and the lead concentrate contains very little zinc. These concentrates can then be sent to the respective smelters. The Broken Hill ores, on the other hand, are finely crystalline, and the lead and zinc sulphides are intimately associated with each other and with heavy minerals such as iron pyrites, garnet, rhodocrosite, and rhodonite. This ore when subjected to concentration methods will ultimately yield two concentrates, but the lead concentrate will carry a high percentage of zinc and thus increase the difficulty of smelting for lead, and, conversely, the zinc concentrate will contain a high percentage of lead, which in addition to making the smelting operation difficult and costly will also result in an almost complete loss of the lead in the zinc concentrate. Recent metallurgical practice at Broken Hill has resulted in some amelioration of these difficulties, but has not yet completely solved them.

The erection of some form of treatment plant should never be undertaken unless a capacity supply of ore is assured. Even in such cases, home treatment of the ore may be a doubtful choice. The

advantages of outside treatment have been succinctly stated by Herbert C. Hoover:

> In considering the working costs of base-metal mines, much depends upon the opportunity for treatment in customs works, smelters, etc. Such treatment means a saving of a large portion of equipment cost, and therefore of the capital to be invested and subsequently recovered. The economics of home treatment must be weighed against the sum which would need to be set aside for redemption of the plant, and unless there is a very distinct advantage to be had by the former, no risks should be taken. More engineers go wrong by the erection of treatment works where other treatment facilities are available, than do so by continued shipping. There are many mines where the cost of equipment could never be returned, and which would be valueless unless the ore could be shipped. Another phase of foreign treatment arises from the necessity or advantage of a mixture of ores—the opportunity of such mixtures often gives the public smelter an advantage in treatment with which treatment on the mine could never compete.[9]

Drainage.—In a new region where there is danger of flooding through excessive quantities of underground water, pumping expense may be prohibitive to profitable operation. This was the case, for example, in some of the Australian deep-gravel mines, where great sums were lost in attempting to drain the workings. Eventually certain projects were abandoned, after millions of pounds of shareholders' money had been expended without avail.

Great sums were also spent by the Pekin Syndicate in draining their Honan coal mines, no less than four sets of pumps, each larger than its predecessor, being installed before the water was conquered.

Availability of power.—Mining operations consume great amounts of power. If this can be supplied from waterfalls near by, the costs will be materially lower than if power must be generated by steam, oil, or gas units burning an inefficient fuel such as wood or oil or coal hauled over long distances. The capital expenditure for a hydroelectric plant, for example, may be large, and before installing one the additional amount to be spent should be proved justifiable by a saving in power costs under the contemplated system.

Lighting, ventilation, and safety measures.—These items vary according to geographical location, nature of the deposit, position, size, depth, and other factors. Most mines must be thoroughly ventilated as a matter of safety and labor efficiency. A small gold mine can operate with carbide as the lighting medium, whereas a large copper mine can save money by the installation of electric

[9] Hoover, H. C., *Principles of Mining*, p. 40.

lighting. It has been proved that some races of miners will work with a fair degree of efficiency under conditions of ventilation and safety that would not be tolerated by other races.

Availability of supplies.—The cost of mine supplies, other than explosives, seldom amounts to more than 20 per cent of the total operating cost, and this item is almost always a minor factor in estimating costs. For this reason it is possible to carry on mining operations at great distances from the points whence supplies and materials must be drawn. In South Africa, where the supplies for mining are largely drawn from the United States and northern Europe, the cost of supplies per ton of ore handled is not more than 10 per cent greater than it is in the United States.

The desirability of a large supply of suitable timber in the neighborhood of a deposit with soft supporting walls has already been mentioned.

Transportation.—Experience shows that the costs of shipping the product and transporting equipment and supplies are more frequently underestimated than any other factor of costs when valuing a mining project in one of the remote districts of the world. Not only will a lack of cheap and reliable transportation by water or land lay a heavy burden upon operating cost for charges on haulage itself, but it will increase expenses and lower efficiency by causing delay and uncertainty, and costly interruptions, through periodical discontinuance of transport; these all leave their impress on the profit-and-loss sheet.

The costliness of delay in transportation may be indicated by the experience of a gold-dredging company operating in Alaska, where the difficulties encountered in the delivery of machinery caused the dredges to be completed fully two years later than the time estimated for initial operation—by which time the accumulated overhead expenses had consumed all the company's capital. The exploitation of a mining property in northern Burma involved the construction and maintenance of fifty miles of jungle roadway and a passenger ferry, mainly for the purpose of insuring a supply of laborers.

Labor, wages, and efficiency of personnel.—The cost of labor will usually account for at least 60 per cent of operating expense, and is therefore of extreme importance in the estimation of probable disbursements.

The availability of a large supply of cheap local labor should

never lead any engineer to assume that the labor cost will be proportionately cheaper per ton. As a matter of fact, labor costs are almost always greater in districts depending heavily upon native workers. Irresponsibility, incapacity to use explosives and machinery, lack of judgment and initiative, and need for constant supervision are such marked traits of most of the races furnishing large bodies of cheap labor that these characteristics more than counterbalance any saving in wages. Any mine management expecting to accomplish such a saving must be prepared to undertake a considerable period of training and building up a competent and dependable local corps of workers.

The problem of wages and efficiency of labor is so extensive that it has been given detailed consideration in chapter 24. For the purpose of estimating future operating cost it will in general hold that little fluctuation in the average item for labor, owing to operation in various districts of the world, may be expected.

Climate and altitude.—Both climate and altitude have a direct effect on the cost of mining, principally because they affect labor supply. A mine in the tropics or sub-tropics cannot be operated by men of northern European races, and must therefore depend on native labor.

Climate and altitude also profoundly influence the efficiency of the staff, and this directly affects working cost. If a mine is in a tropical climate where malaria is prevalent, there must be a continual shifting of members of the staff—some going home to recuperate while others take their places—and other members may be suffering from malaria or its effects to such a degree that they are inefficient even though not ill enough to stop working. This condition will result in higher administrative charges and a lowering of efficiency throughout the entire personnel of the mine.

Another extreme is found in Alaska, where the long, severe winters place such a limitation on human effort that gold-dredges, for instance, can be operated only six or seven months in the year. This occasions heavy administrative and capital charges, for although the plant is idle nearly half the year, staff and offices must be maintained.

The effects of extremes of climate and altitude upon transportation cost need only be mentioned.

Efficiency of management.—There is a tendency for engineers visiting a mine for the purpose of examination and valuation to be

hypercritical of the local management. Considering the high mental quality of the group who now enter the profession, the general excellence of engineering education, the free discussion and interchange of technical information, and the activity of the technical press, it may well be doubted whether there are many opportunities for any startling reductions of operating cost at a particular mine. New metallurgical inventions may be applicable in some instances, but the chances are that at any mine that has been in operation for some time the management and the metallurgical practice are those best suited to local conditions. The valuing engineer should therefore be extremely hesitant about expecting that any change in management will materially lower cost of operation.

Resident administration.—The costs of administration at mine and plant will include such items as salaries for manager and staff, rent, office supplies, office expenses, traveling expenses, telephone and telegraph, local taxes, workmen's compensation, insurance on stock of supplies, pensions, medical and welfare expenses, and extraordinary costs such as those incurred through strikes. Costs for resident administration, although they may be lowered by efficient management, will not vary greatly from place to place, and most proposed changes will have no great influence upon unit cost.

Maintenance.—The cost of maintaining the efficiency of plant and equipment during the life of the mining enterprise may be considered as a proper operating cost. Maintenance items include repairs and renewals resulting from wear and tear and involving periodic repair work and replacement of outworn parts. Proper valuation of a mining property should allow for an annual operating expenditure for replacements and repairs equal to from 5 to 10 per cent of first cost of plant and equipment.

It may be well here to distinguish between the terms "maintenance" and "depreciation." For valuation purposes, depreciation is never considered as an item of operating cost. Depreciation is not a current working cost item, but an annual book figure intended to show that a part of the original capital value of the plant has been written off to provide for the amortization of this capital during the estimated life of the plant. This allowance for depreciation is charged off on the accounts to the limit provided by federal income tax regulations, whether or not this amount is justified by the actual state of usefulness of the plant and equipment, which, if they are properly maintained, should not be appreciably reduced.

"Natural" depreciation is the wearing out of a plant to a point

where it cannot for that reason be used. This is a relatively rare occurrence in mining if the plant is properly maintained.

"Functional" depreciation results in the replacement of plant or equipment because of (1) obsolescence through improvement in technology, (2) cessation of the demand the structure was designed to serve, or (3) inadequacy of plant. Such depreciation cannot, of course, be anticipated at the time a valuation is made. The replacement of plant or equipment in order to take advantage of improvements in technology that will give higher recovery or lower costs will be undertaken with the intention of saving money, so that depreciation on the new plant may be covered by the enhanced profits resulting from its use. Cessation of demand for the services for which the structure was erected has been responsible for the abandonment of most of the deserted blast furnaces and other smelting works found throughout the country. In the mining industry, as has been repeatedly said, the depreciation on fixed capital items will probably be 100 per cent at the end of the mine's life. Inadequacy is commonly a capital charge resulting from a need for greater capacity. Although, for example, a shaft with its hoisting and pumping equipment may be incapable of rendering service at an increased depth, it may be presumed that this would not happen had not new ore reserves been developed and additional capital value thus been created, in which case the cost of the new equipment may be charged as a capital expenditure against the new ore. Such future capital expenditure need not be considered in the estimation of working costs in a report based on ore reserves developed at the time of valuation.

METHODS OF ESTIMATING FUTURE COSTS

Three methods of estimating future costs are open to the examining and valuing engineer:

1. If the mine has been in operation for some time, the records may be analyzed and, if no radical changes are planned, the figures may be used as a basis for estimates. Although this method is by far the simplest, it demands great perseverance and insight, for the accounts of most mining companies, as will be shown elsewhere, do not always reveal the true operating cost at a glance.

2. If the mine has no reliable production records, the method of comparison must be used, in which the engineer assigns a figure to each factor of cost upon the basis of his experience and the records of similar mines for which figures are available.

3. As a last resort, cost figures may be derived by experimental

operations. This method is expensive, but may be valuable if dependable data can be obtained in no other way.

In applying any of these methods, however, care should be taken to make sure that the records used as indicators of cost extend over a reasonably long period. A tendency prevails among mine managers to submit cost statements that neglect unfavorable periods, and to select for presentation figures for the prosperous years when mine and plant made the best showings.

Analysis of operation records.—If the business under valuation has been in operation for an extended period, these long-term records may be used as a basis for estimating future costs. The engineer should, none the less, satisfy himself as to the reliability of the figures that he obtains by examining these records and should also adjust them to conform to any radical change in method that may be contemplated.

Comparison with costs in similar situations.—If the property is undeveloped and no ore has been treated on a large scale, the difficulty of cost estimation is much greater. Each factor of cost must be assigned a figure that in the last analysis is "sensed" by the engineer, guided by his experience and an examination of available records of comparable mines.

The first recourse would be to the cost figures of mines in the same district. A simple problem is presented by the determination of costs of an undeveloped mine lying between two properties whose long-term records are open for inspection.

If no such data can be obtained the engineer must fall back on an analysis of the operating costs of mines farther afield, choosing from his own experience or from the voluminous literature of mining and metallurgy some case which in his estimation most nearly fits the present situation.[10] He should take the costs of mining, milling, development, recovery, and equipment in known cases, and from them deduce the probable cost in the case under consideration.

The basic figures for these deductions may be drawn from several different sources. Assume that the engineer has to value a lead-zinc-silver deposit in the Northern Shan States of Burma; assume that the deposit is comparable in size and mining characteristics with the Broken Hill (New South Wales) deposits but that obvious dif-

[10] Operating costs for various mines are to be found in the periodical press and in such books as: Finlay, J. R., *The Cost of Mining,* 3d ed.; Skinner, E. N., and Plate, H. R., *Mining Costs of the World;* G. A. Roush (ed.), *Mineral Industry Yearbook;* and Peele, Robert (ed.), *Mining Engineers' Handbook.*

ferences in the ore indicate metallurgical difficulties comparable, not to those at Broken Hill, but to those at Coeur d'Alene, Idaho. These two places combined being the nearest approach to the Burma conditions, he will take for his comparison figures the Broken Hill mining costs and the Coeur d'Alene treatment costs. In Burma exists an abundant supply of cheap labor, whereas at Broken Hill, labor is scarce, high-priced, and troublesome; therefore the Broken Hill figures for mining labor costs should be corrected to fit the Burma labor supply. The same correction must be made in the labor cost for milling at Coeur d'Alene; and so, by cut and try, throughout the whole range of labor cost, costs of supplies, and costs of transportation to market, the engineer weights known figures in order to arrive at a tentative figure for the estimated probable cost of working the Burma deposit.

Cost records appearing in Peele's *Handbook* indicate that post-war costs may be roughly approximated by adding 75 per cent to pre-war figures. The effect of financial disturbances since 1929 upon mining costs remains to be determined, but it is safe to say that a 75 per cent increase over pre-war figures is now much too high.

Experimentation.—If the mine is in a new district, and the costs of development and treatment for a closely comparable situation cannot be obtained, the management may resort to the method of experimentally deriving costs of operation by careful tests on a small scale. This method is expensive and time-consuming but is frequently prudent. Deductions from even the most exact small-scale experiments, however, should be made with full allowance for a large factor of safety. This is especially true if the installation of new metallurgical inventions is contemplated.

If there is doubt concerning the metallurgical treatment cost or the process best adapted to beneficiate the ore, trial shipments may be made to testing works or to plants where a suitable process is in operation on a large scale.

If this is not feasible it may sometimes prove economical to erect a small pilot plant for trial tests. At the Ajo copper mine, where a new form of leaching process was introduced, a small-scale plant, after many laboratory tests were made, was built, capable of treating a few tons daily. Guided by the results of this work, a 40-ton unit was installed and ran for eighteen months. At the end of this time a 5,000-ton plant was constructed and was naturally a success; whereas if it had been built on information obtained from laboratory results it might well have been a failure. Although it is

almost an axiom that if a mine cannot profitably be operated by known processes it should not be acquired, yet—as in the case of Ajo, which at that time needed a higher recovery to attain success —there are attractive properties that must be operated on new lines in order to be successful. But no new process should be adopted for full-scale production until it has been thoroughly investigated by sufficient small-scale experimentation.

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Chapter 8

Financial Provisions

All discussion in previous chapters has tended toward one end—the determination of the degree of risk assumed through the acquisition of a mining property. With all the conditions and factors of a situation in hand, the engineer will be able to state the terms of his valuation problem and to resolve them into an answer to the question: "What profit may this mine be expected to pay?"

It has been shown that the net recoverable value of the ore reserves, less all costs, will yield the net profit that may be won. This profit, however, is not the value of the mine. If all the ore were extracted and sold within a short period, this net profit would be closely equivalent to the value of the property; but this is impossible, and thus a most important factor is introduced—the *time* during which the invested capital will be employed. The mine's worth at the present time may therefore be considered to be the net profit suitably discounted.[1] In more emphatic terms, the present value of an enterprise is considerably less than the total dividends it may be expected to pay. The difference between the net profit, or total dividends, and the present value is a sum of money that represents the suitable discount demanded to cover the factors of time and risk.

The present value of an enterprise is the same thing as the present value of the total dividends it may be expected to pay. This present value is the amount of money that can justifiably be put into the enterprise for the purchase of the mine, plant, and equipment, on the assumption that this money will be returned within the term of the life of the enterprise, and that the investor will also receive, in the form of dividends, a substantial return on the capital he has laid out.

If rates of interest be assigned for dividends and the life of the mine be approximated, the present value may be calculated by the technique of "amortization." If this present value is not sufficient

[1] Hoskold, H. D., "The Valuation of Mines of Definite Average Income," *Trans. A. I. Min. E.*, Vol. 33 (1903), pp. 777–89.

to cover capital expenditure for the purchase, development, and equipment of the mine, the project is economically unsound.

The simplest way for a young engineer to value a mine, then, is to:

1. Determine the net recoverable value of the estimated ore reserves.
2. Subtract from this the total cost of obtaining this value.
3. Weigh the resulting profit against the risk assumed by undertaking to extract the ore in a given time with a given capital expenditure, allowing for the return during that time of this expenditure plus normal interest on it plus substantial dividends. This weighing process, as stated above, is accomplished by using the technique of amortization, a concrete example of which will later be given.

DEFINITION OF CONCEPTS

The meanings of the various terms used in this chapter must be defined and explained if a clear conception of the method is to be obtained.

Present value.—The present value of a mine may be considered, for the engineer's purpose, to be a sum of money that may be allowed for the purchase, development, and equipment of a mine, with the expectation of receiving for this capital expenditure, during the estimated life of the mine, the return of this capital plus a substantial profit commensurate with the risk involved in the venture. This definition will be reduced to a formula in the section on "Amortization."

Capital expenditure.—The amount of money required for the purchase of the right to mine a deposit, for its preliminary development, for the purchase of adequate equipment and plant to operate it, and for working capital, is termed capital expenditure.

Life of the mine.—The period during which the mine will be totally depleted cannot be exactly determined. The magnitude of this time factor must be approximated in some way, however, and for the purpose of calculating present value, the life of the mine may be defined as the time in which, through the employment of the available capital, the ore reserves—or such reasonable extension of the ore reserves as conservative geological analysis may justify—will be extracted.

Redemption of capital.—A mine is a wasting asset, the capital value of which will in time be reduced to zero. The ore is depleted by every ton extracted, and the salvage value of plant and equipment is negligible—seldom sufficient, in fact, to pay for transporting materials and machinery elsewhere. The wise investor expects that his capital outlay will be repaid to him during the life of the mine; and any financial program for a mining business must allow for the redemption of this capital during that period, which may often be no longer than five or ten years.

If the investor were to put his capital into the acquisition of a non-wasting asset, the rate of redemption would be of little consequence. For example, if he were to purchase a farm instead of a mine, he might assume when determining the present value of his property that with reasonable care his purchase—that is, the farm land and buildings—would be as valuable fifty or a hundred years hence as at the present time. He could therefore feel fairly certain that a small sinking fund, placed at compound interest over those years, would make the return of his capital a small item of expense. But if, as has been pointed out, the investor must have his capital returned to him from mining operations within the relatively few years required to work out the ore reserves, a considerable part of the annual net profit should be conceived as set aside to redeem the capital outlay.

This concept of the redemption of capital during the life of the enterprise implies that a sinking fund should be set up to provide for the reinvestment of part of the profits, presumably placed in sound securities paying compound interest. Actually, and contrary to the implication, few mining businesses set up such sinking funds. Directors usually prefer to declare the full earnings as dividends, leaving to the individual investor the problem of reinvesting such part of his dividends as he may wish to consider as return of capital. In exceptional cases sinking funds are set up by some mining companies for the purchase of other property when their mine is depleted. But even though the methodical creation of a sinking fund for redemption of capital is not a common practice in mining administration, a deduction from operating profit to cover return of capital should be regarded as a fundamental part of the mine valuation process, for it indicates clearly the wasting nature of the enterprise and is one factor used to measure the amount of risk assumed by the investor when placing his money in a business containing so many elements of speculation.

Normal interest.—The investor expects that he should receive, in addition to the bare return of his capital, a rate of interest on the money thus laid out equal to the prevailing rate paid on sound securities or on savings deposits, which may be termed the "normal rate." This should not be less than 4 per cent; and 5 per cent is more usual.

Interest is defined as payment for the use of money or for the forbearance of a debt. The interest bears a fixed ratio to the loan and is to be paid at certain agreed times, usually semi-annually or quarterly. The money lent or due is called the principal; the sum paid for the use of it, the interest; the fixed ratio, expressed as a per cent, is the rate. *Simple interest* is that arising solely from the principal, and even though unpaid, does not itself bear interest. *Compound interest* requires that if the interest falling due on the principal remains unpaid, it is added to the principal and is itself chargeable with interest. When dealing with sinking funds, compound interest is always used. The sinking fund formula is given on the following page.

Interest also connotes the idea that money should earn something, whether it is actually loaned or not. For instance, a man may carry $100 in cash about with him for the comfortable feeling it gives. But if he deposited this sum as part of a savings account, his bank would pay him, say, $2 a year. A true account of his personal expenses during a year should include a charge of $2 for the luxury of carrying this amount of cash in his pocket; for although in this instance there was neither borrower nor lender, there might have been. Likewise, when interest is discussed in mine finance, it may not imply a loan but merely that the money might have been lent; and therefore interest is properly chargeable whenever money is used in mining operations.

The power of compound interest is little appreciated by many. Without considering any very long period, which would give sums of fantastic magnitude, it may be pointed out that $1 at 6 per cent compound interest for 100 years amounts to $339; at 10 per cent, to $13,780.

The following problem illustrates how compound interest works to reduce the periodic deposit needed for repayment of invested capital. Suppose $1,000 is invested in a mine, and the investor desires to know what sum must be set aside annually, from dividends received, in order to repay the $1,000 invested capital, in ten years, with savings-bank interest of 4 per cent. The problem may be easily

solved by the use of compound interest tables to be found in any of the various handbooks on investment. The formula used is:

$$d = \frac{r}{R^n - 1} S$$

where $d =$ uniform deposit to be made at the end of each period; $r =$ rate of interest; $R =$ rate of interest plus 1; $n =$ number of years; and $S =$ the amount of the sinking fund. Substituting the values $R = 1.04$, $r = .04$, $n = 10$, and $S = 1{,}000$, d is found to be \$83.29, the annual deposit required. If the fund did not bear interest, the annual deposit would obviously be \$100.

This example makes it apparent that \$1,000 invested in a mine with a ten-year life must return 8.33 per cent interest annually in dividends in order barely to redeem the money invested. If the investor received only this rate of interest on his capital, he would be in the position of the newsboy who bought his papers for a penny and sold them for a penny and considered as ample profit his opportunity to yell. The example also emphasizes the point, later to be made, that short-lived enterprises, such as most mines are, must pay very high annual returns even if the investor is to receive no more than a "chance to yell" plus the bare return of his capital at the end of the mine's life.

Profit.—When one speaks of the interest on a mining investment, the rate mentioned ordinarily consists of the normal rate plus a substantial additional rate that represents the profit that should accrue in proportion to the hazardous nature of the mining business. In this sense, the rate of interest in most forms of mining should be high; to be satisfied with less than 10 per cent annually would show a lack of acumen, and a much higher rate would not be exorbitant for most mining ventures.

If the return from the investment were merely sufficient to insure the redemption of capital and the normal rate, the investor would have jeopardized his money for no more gain than would have been received had he deposited it in a savings-bank. It is the lure of enormous profits that encourages the share-buyer to venture his money in the exploitation of mines, in the hope that it will yield dividends commensurate with the risk assumed.

Mining operations have been divided by Pickering[2] into three

[2] Pickering, J. C., *Engineering Analysis of a Mining Share*, McGraw-Hill, pp. 53–60.

classes on the basis of the rate of interest that may be considered adequate for each class. He places the American porphyry copper mines in the first class, and in analyzing the status of the Utah Copper Company finds that 7 per cent interest and 4 per cent for the sinking fund would give a fair return. Seven per cent profit was also thought to be adequate for large gold mines such as the Homestake. Such mines as those of the Rand, in which the geological conditions are uniform and past working results have shown reasonable agreement with predictions, should pay at least 10 per cent, returning capital at the rate of 4 per cent, although if one of these mines shows little promise of a long life the return should of course be greater.

Speculative mines must be valued individually and the interest rate should be much higher than 10 per cent.[3]

Amortization.—Amortization, as herein used, is the process of estimating whether an investor is justified in hazarding a sum of money to purchase the mine and its equipment. By the use of amortization tables derived from what is known as "Hoskold's formula," the present value of one dollar of dividend accumulating during n years, within that period returning capital expenditure at r_1 per cent annually with annual interest (normal plus profit) at r_2 per cent, may be calculated. This present value of one dollar may be multiplied by the total annual dividends to give the present value of the mine. This value is equivalent to the sum of money that may be justifiably allowed for purchase of the mine and expense of development and equipment, if the investor is satisfied with the return of his capital in n years, r_2 per cent on his investment, and the possibility of further profit if ore is later developed in excess of the estimated amount.

The present value of one dollar of dividends may be calculated by the following formula:

$$P = \frac{1}{\dfrac{r_1}{(1+r_1)^n - 1} + r_2}$$

in which P = present value of \$1 annuity; r_1 = interest rate on capital redemption fund; r_2 = interest rate of annuity or dividend; and n = period of annuity payments (years).

[3] See Hoover, H. C., *The Principles of Mining*, pp. 42–43.

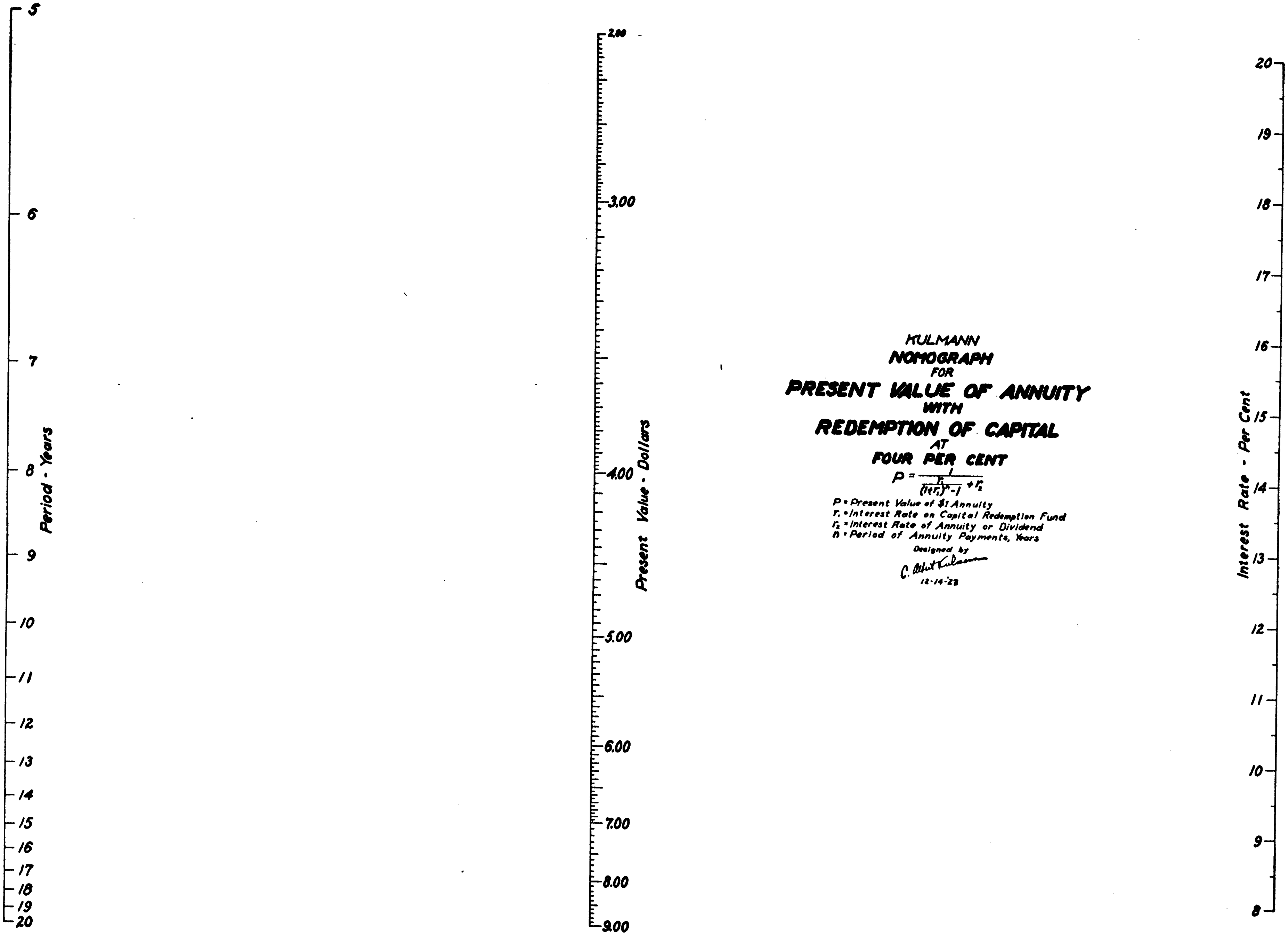

FIG. 5.—Nomograph for Use in Calculating Present Value

For example, suppose one wishes to calculate the present value of a $100 share paying $6 annually for 20 years, and redeeming capital by a 4 per cent sinking fund. Then

$$\text{Present value} = \cfrac{1}{\cfrac{.04}{(1.04)^{20} - 1} + .06} = 10.68 \times \$6 = \textit{\$64.08}$$

Calculation is simplified by the use of standard amortization tables.[4] These tables have been reduced to a nomograph, Figure 5, which when used with a straight-edge will be sufficiently accurate for most determinations of present value in mining.

This nomograph is constructed for periods of life of from 5 to 20 years, which limits are considered adequate for almost all mining valuations. The dividend rate is calculated between the limits of 8 and 20 per cent. No mining engineer should ever use a dividend rate of less than 8 per cent under any circumstances, but in some cases more than 20 per cent can be fully justified in mining investment.

DETERMINATION OF PRESENT VALUE

Mines may be divided into two classes from the point of view of the accountant: those that pay their way from the grass-roots, thus furnishing their own capital; and those for which outside capital must be found.[5]

The richest mines have built their plants and paid for equipment and development out of profits; there has been a continual growth, so that the original capital is only an insignificant fraction of the total amount of capital actually invested in the property. Neither is there any great need to distinguish between "capital account" and "operating cost," for all expenses incurred may well be termed operating cost.

The low- and medium-grade mines, however, must be provided with initial capital until the time when they reach production. This capital must be charged off with interest over the period in which it is desired to redeem it; in other words, it is amortized. This period is determined by estimating the life of the mine.

[4] See Hoskold, H. D., *Engineers' Valuing Assistant;* Hoover, H. C., *Principles of Mining,* pp. 46–48; Saliers, E. A., *Accountants' Handbook,* p. 465; and standard investment handbooks.

[5] Goodchild, W. A., "The Computation of the Present Value of Developed and Undeveloped Mines," *Trans. Inst. Min. & Met.,* London, Vol. 18 (1908–1909), pp. 367–411.

Present value of a share.—The technique of amortization may easily be demonstrated by contemplating the purchase of a mining share, which is a fraction of a mine, and is likewise a wasting asset. In this case, capital expenditure includes only the amount that must be paid for the ownership of the share. Assume that the share, quoted at $25, will pay an annual dividend of $5 for a period of ten years. Making use of the nomograph, Figure 5, the present value of an annual dividend of $5 over ten years at 10 per cent, replacing capital by reinvestment of an annual sum at 4 per cent, is 5 × $5.45, or $27.25. The quoted price is therefore seen to be somewhat too low under the conditions imposed.

Present value of a mine.—Take, as an illustration of the method used in the calculation of the present value of a mine, the hypothetical case worked out in chapter 6, Examples 5–7.

EXAMPLE 8

The ore reserves of this mine were discovered to be 500,000 tons with an average value of $9.64 per ton. It is possible to state this value exactly in the present case, as a gold mine was chosen for simplicity in demonstration, and the selling price of gold is normally fixed by law. The estimation of selling price of all other metals is subject to the conditions explained in chapter 10.

Deduction of 10 per cent from assay value, to allow a margin of engineering safety for errors in sampling and for dilution, results in an adjusted value of $8.68 per ton. The percentage of recovery will be assumed to be 90 per cent, and the net recoverable value per ton of ore would thus be $7.81. Operating costs in this instance, as defined in chapter 7 and including a factor of safety but not including depreciation, will be assumed to be $5 per ton; this gives an operating profit of $2.81. A further deduction of 20 per cent to cover city office expense results in a net profit per ton of $2.25, available for dividends.[6]

[6] Example 8 was evolved in 1933 under the particular conditions existing at that time. If we apply the factor of safety of 50 per cent recommended on page 134 to cover postwar uncertainties, this would mean the addition of $2.50 to operating costs, which would wipe out all profits in the assumed enterprise of the example. At this example is merely an illustration of how to proceed, it has been deemed advisable to leave the example as it is and not try to adjust the whole section to postwar conditions.

These deductions from gross value of the ore per ton may be summarized as follows:

Gross value of the ore per ton	$9.64
Deduct 10 per cent for margin of safety (sampling error and dilution)	.96
Adjusted value	$8.68
Deduct 10 per cent for metallurgical losses	.87
Net recoverable value	$7.81
Deduct operating cost	5.00
Operating profit	$2.81
Deduct 20 per cent for city office expense	.56
Net profit per ton available for dividends	$2.25

The practice of deducting 20 per cent of the operating profit for city office expense cannot be well defended logically, although the method is commonly used. It is possible, for example, that a venture might have a large city office overhead charge even though no operating profit were made. A more substantial basis for this estimate would be to deduct, say, 5 to 10 per cent of the gross value of the ore per ton. In the above example, if the deduction for city office expense were taken as 6 per cent of the gross value of the ore, the item would be substantially the same.

Assume that this mine will be equipped to work one level of one hundred feet in depth each year. As nine levels are now developed, the life of the mine, excluding the prospective ore, will be nine years; and the annual tonnage of proved and probable ore treated will be 500,000 ÷ 9, or 55,555 tons per year. This annual tonnage, multiplied by the net profit of $2.25 per ton, will give an amount of $125,000 as annual profit available for dividends.

It is now possible, through the use of the nomograph, Figure 5, to discover the present value of a mine yielding a dividend, or annuity, of $125,000 yearly for nine years, returning the capital expenditure through a fund invested at 4 per cent during that period and paying any desired dividend rate.

First, suppose that one wishes to discover the present value of this dividend of $125,000 for nine years at the modest rate of 10 per cent annually, at the same time replacing capital by a sinking fund at 4 per cent. The nomograph shows that the present value of one dollar in dividends under these conditions is $5.14. This, when multiplied by $125,000, yields a present value for the dividend of $642,500; this amount is the present value of these nine annual dividends, and is likewise the present value of the mine itself.

This sum of $642,500 represents the amount that a buyer of the mine might be justified in paying for purchase price and equipment of the mine, if he were willing to accept 10 per cent on his investment and the return of his capital outlay in nine years. In addition he would have the speculative value of the undeveloped, prospective ore at the bottom of the mine. If, however, he desired a dividend rate of 20 per cent, the present value, calculated in the same manner (nomograph figure, $3.40), would be only $425,000.

This comparison shows that the greater the rate of return desired, the lower will be the present value. It also serves to reveal a paradox that indicates the importance of the economic factors in a mining venture. Here is a mine in which the gross value of the proven and probable ore is $4,820,000, and in which the net profit to be made from the proved and probable ore is $125,000 × 9, or $1,125,000. Yet the greatest amount that any operating company satisfied with the low interest rate of 10 per cent is justified in paying for this mine and the equipment to handle it is $642,500. In other words, the income from more than 40 per cent of the ore in the mine must be written off to pay for financing the enterprise. If 20 per cent were the desired rate, more than 60 per cent of the income from proved and probable ore must be devoted to insuring the investor. This explains why many mines cannot easily obtain financial backing. The price at which they are offered does not allow for the large proportion of the net profit that must be deducted to pay for a firm financial structure and to cover the risks inherent in the mining business.

A caution must be given that the amortization formula has no magic power to assure safety in mining investment. The two factors upon which it mainly depends—the life of the mine and the interest rate for dividends—are necessarily estimated, or "sensed," and any variation in these estimates will profoundly affect the resulting figure for present value. For instance, if the estimated life is twenty years and the actual life ten years, the factor n will be in error 50 per cent. A useful rough rule is to require that a mine should show reasonable geological evidence that it would give an annual profit of at least 25 per cent on the capital expended. This would give assurance that no sound project would escape and that no dubious project would be accepted. Even at this figure the ordinary mining enterprise is not extremely attractive; it is only when the calculations come out at 30 or 40 per cent per annum (which rates have not been included in the nomograph) that Eldorado

seems at hand. It must be admitted, however, that this figure of 25 per cent is too high to be applicable to certain exceptional mines having consistent and extensive deposits, the ore from which may be easily and cheaply treated. Warning should be made against the danger in considering gross production in estimating future value. Most small mines fail to show a profit when the entire life is taken into account.

The following formula has been supplied by President Francis A. Thomson of the Montana School of Mines:

$T =$ Tonnage of recoverable mineral in the area.

$V =$ Gross value per ton.

$O =$ All operating costs per ton.

$T(v - o) = Ro =$ Total operating return.

$Ta =$ Annual tonnage.

$\frac{T}{Ta} = n =$Life of mine ("n" in Hoskold).

$Rn =$ Total net return.

$E =$ Total non-operative expense, cost of property, development, equipment, taxes, administration, sales.

$Rn = Ro - E$

$\frac{Rn}{n} = A$ in Hoskold's formula.

$P =$ Present worth (depends on interest rate).

Another rough method of mine (or mine share) valuation, which may be used as a check against the method here proposed, is given by J. H. Curle.[7] It reflects the truism (discussed at length in chapter 17) that most mines are valued too highly by a prospective seller and likewise that most mining shares are overvalued on the stock market. His method, based on the factor of "net profit in sight" and applicable only to producing mines, follows:

a) The net profit in sight in the ore-reserves must be equal to two-thirds, or 66 per cent, of the market valuation.

b) The main points of development in the mine must show no material falling off in bulk or value of ore.

c) The yield on the investment must be 15 per cent.

These three factors are a basis; but they are susceptible of permutation to a certain extent. If, for example, instead of being 66 per cent, the profit in sight were 100 per cent, it is clear that the good appearance of the mine at all the main points of development is not such a vital matter, and a falling-

[7] *Gold Mines of the World*, 3d ed., pp. 49–51.

off in value at some of these points might be noted without undue alarm. At this figure the investor is assured of getting his money back. All he risks is the interest on it, and it would take no great further amount of ore to make that good to him. . . . .

On this basis of valuing a mine it will be noted that 66 per cent of the market valuation is to be in sight, and that this is to be repaid at the rate of 15 per cent a year, or, in other words, over a period of about 4½ years. Under normal conditions, therefore, my basis of valuation entails 4½ years ore-reserves blocked out ahead.

How does this tally with the purely technical working of the mine? A high authority has laid it down that, as regards cheap working, the economic limit of blocked-out reserves is equal to a three years' supply. If, on the head of this, I require a further 1½ years' supply, no doubt an extra, though not large, expense is entailed; but I consider such larger reserve to be a necessary security, and look on the extra cost involved in the light of an insurance premium.

ALLOWABLE CAPITAL EXPENDITURE

The present value of a mine, as calculated by the method shown in Example 8, will be the maximal capital allowance for the purchase of the property and its preliminary development, and for the purchase and erection of plant and equipment.

Purchase price.—If the owner can be shown that the present value of the property, less estimated costs of development and equipment, is much less than his asking price, tactful negotiations should lead to reduction of this price. If he will not reduce his asking price, the proper thing for the engineer to do is to depart and leave him to dream his iridescent dreams undisturbed.

Preliminary development.—The purchaser of a mine that has not reached the stage of production must allow in his financial program for a capital expenditure sufficient to carry on development work to the point where revenues are received for the sale of the mineral product.

Plant and equipment.—Careful estimates aimed to adjust equipment to a suitable average output for any particular mine will prevent the premature or excessive purchase of equipment before development shows exactly what the ultimate production program will demand.

Owners of rich mines are more than likely to be guilty of spending money in the purchase of equipment in excess of their needs. The necessity for the careful estimation of requirements and prevention of extravagance is naturally somewhat relaxed if bountiful profits are in sight.

The erection of reduction plants before sufficient ore is assured is a common error: the mining regions of the West are dotted with abandoned mills that never paid a cent to their owners and stand as monuments to warn the engineer against wasting his client's money on reduction plants before the mine is sufficiently developed.

Care and experience are necessary in choosing mine or mill equipment and should be supplemented by an estimate of all costs over the operating life of the plant. Schemes for effecting savings in handling of ore through replacement of existing methods should not be approved solely upon the saving in unit cost. For example, a complicated Diesel engine saves greatly on the cost of fuel and would be suitable for a plant near large machine shops in a district where skilled mechanics can be easily engaged and replaced; but the same engine might prove costly at a remote mining camp where a simple slide-valve engine could perform the amount of work required. Again, an outlay of $50,000 to erect an aërial tram was made at one mine to transport 50,000 tons of ore that could have been carried as cheaply in carts without any expenditure for mechanical equipment.

RATE OF MINING

The life of the mine will of course vary according to the rate at which the ore is extracted. It may be argued, on theoretical grounds, that this rate should be the maximum, and that the ore underground should be beneficiated as soon as possible, because a saving in fixed charges—those independent of tonnage treated—would therefore result.

Granting that the most economical rate of exploiting an ore deposit is the maximal rate, what are the practical considerations that prevent the miner from realizing this theoretical speed of extraction?

The factors that limit rapid exploitation of ore deposits have been ably described elsewhere,[8] and the student is referred to that source for a detailed discussion. The five main limitations there set forth may here be briefly outlined.

1. *Cost of equipment.* The installation of equipment, which has low salvage value and the cost of which must almost entirely be redeemed during the mine's life, should not be made in excess of average need during the certain life of the mine. The saving of

[8] Hoover, H. C., *Principles of Mining*, pp. 153–60.

fixed charges is only possible through the use of larger equipment, but the cost of this equipment should be considerably less than the saving to be effected, for obviously it is of no use to invest a dollar in order to save a total of ninety cents.

2. *Life of the mine.* The theory of maximal rate of mining, if carried to its logical extreme, would lead to the depletion of mineral resources at an alarming speed, which in the end would be contrary to the interests of all.

3. *Mechanical efficiency of patchwork plant.* The equipment of most mines growing from small beginnings is often a patchwork resulting from additions from time to time as needed. Any scheme of wholesale operation would demand that any new equipment to replace the old be installed in units large in ratio to the previous plant, or the patchwork nature of the plant would remain and lead to further inefficiency.

4. *Overproduction of base metal.* The general application of the theory of rapid exploitation would also lead to overproduction of metal product, which would quickly depress prices to a point where the advantages of such a rate of operation would vanish.

5. *Security of investment.* The value of mining shares is, or should be, based on the life of the mine, and the investor commonly prefers a mine where development shows a reserve sufficient for several years of operation. The policy of rapid exploitation of a deposit is therefore contrary to the interests of investors, who wish development to be maintained in advance of production.

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Chapter 9

Sale of Mineral Product

Mines that do not themselves possess plants to treat their ores to the point of producing marketable metal must have certain treatment operations performed by others; and therefore many mines sell their product—in the form of either raw ore, sorted ore, or concentrates—to custom smelters. The smelting of ores and concentrates has thus grown up as a separate industry, having its own capital and operating expenses and expecting profits on its operations. The interests of miner and smelter have frequently been at variance, and the history of the relations between the miner and the so-called "smelting trust" has too often been marked by disputes and litigation. Many of these disagreements and misunderstandings could have been avoided by the use of an explicit and equitable contract that would cover most contingencies, insure a fair price to the producer, and allow a reasonable profit to the smelter.

An understanding of the methods of selling ores and concentrates and the contracts under which these sales are made is of prime importance to the valuing engineer for two reasons:

1. He must discover at what price per ton the product of the mine under consideration can be sold, in order to determine the net recoverable value of the ore. He must also satisfy himself that there is a steady market for the product.

2. He must make sure that if the mine is acquired his client will not at the same time assume an unfavorable ore-selling contract that will constitute a virtual lien on the property.

These important considerations require that the engineer examine not only possible but existing contracts with minute care—with the aid of a competent lawyer, if anything is doubtful—to be sure that his client will not be required by a smelting contract to sell his product at a price greatly below its fair value.

ATTITUDES OF SMELTER AND PRODUCER

Position of the smelter.—The smelting company represents a large capital investment, with overhead and operating expenses comparable

to those of any considerable business. To secure the greatest return on this investment, the smelting plant must be supplied with a steady stream of ore that will keep it working to capacity. The smelter is therefore, in the long run, dependent upon the continuance in production of a number of mines operating at a profit. Moreover, even if the smelter does not have to meet competition, it should presumably avoid exacting a charge that would discourage the shipment of sufficient ore to maintain the capacity operation of the smelting plant, or that would encourage a competitor to enter the field.

The difference between the gross value of the metals in the ore and the payment tendered by the smelter for the products derived from that ore should theoretically represent the costs of smelter operations, losses in smelting recovery, expenses of shipping, refining, taxes, selling of product, depreciation, and interest on smelter investment and on product during treatment and transit, plus a profit to the smelter commensurate with the risk assumed. Actually, the deductions charged against each producer's account are not truly representative; and when brought to the point, the smelter manager or ore buyer no longer maintains that these deductions do actually represent true losses and expenses. He defends himself by stating that the average producer, if paid full market price for his metal, would object strenuously to a treatment charge that would cover all these items. All losses and costs, he will state, must be borne by the ore, but he contends that it "softens the blow" if traditional deductions are scattered throughout the settlement sheet.[1] This method of concealing profits, however, is unsound, and leads to opportunities for the smelter to take advantage of the small producer in innumerable ways.

The smelter is in business to make a profit, and it is granted that he is under no obligation to act as a philanthropist; but the small producer is entitled to know at the time a contract is signed what deductions from the value of his ore are actually justified and that the charges imposed carry no excessive hidden profit for the smelter.

Position of the small producer.—The payment tendered by the smelter to the mine operator for the product of his mine (which amount is equal to the net recoverable value of the ore) must cover the costs of mining and mine treatment and, if the enterprise is to be profitable, capital return and dividends. If the smelting charge is

[1] Riter, George W., and Joseph, H. S., "Grievances," *Mines & Minerals,* Dec. 1906, pp. 220–21.

unduly high, the mine's dividends will be lessened, and if the enterprise continues to be unprofitable it will cease to produce.

The organization of a large mine-operating company makes it possible for its officials to know what a fair smelting charge should be; its engineers and consultants are likely to know as much about the costs of all forms of ore treatment as does the smelting company. The small producer, however, has no such protection, and since he feels at the mercy of the smelting company he often makes no attempt to study the complicated provisions of the contract and accepts without question all the provisos, when some investigation, conducted with ordinary business sagacity, would probably enable him to point out wherein he is being dealt with to his disadvantage.

The small producer can only protect himself, then, by obtaining expert advice on the terms of the contract which he is offered and by ascertaining whether or not the figures filling the blanks in that contract will assure him a fair return for his product.

DEDUCTIONS FROM GROSS MARKET VALUE OF ORE

The difference between the gross value of the marketable constituents of the ore as determined by assay, on the date of settlement, and the return to the miner, has been analyzed by Arthur B. Parsons,[2] and may be outlined as follows:

1. Smelting charges and metallurgical losses.
   a) Nominal treatment charge or working charge, which often fluctuates with the value of the ore, with the content of some constituent, or with the market quotation for some constituent.
   b) Deductions from the assay content (for metallurgical losses).
   c) Deductions from the market quotations of the various salable metals.
   d) Penalties imposed because of the presence of undesirable constituents.
2. Marketing charges, or charges against the ore that for convenience are often paid by the smelter on behalf of the miner and charged on the settlement sheet.
   a) Freight on ore from mine to smelter.
   b) Demurrage.
   c) Check-weighing and sampling costs and sometimes umpire assaying.
   d) Freight on lead or copper to refinery.
   e) Duties and customs charges, if the ore is of foreign origin.

MAIN FEATURES OF A CONTRACT

Although it is probably impossible to draw up an ore contract that will cover the manifold contingencies that may arise between

[2] Spurr, J. E., and Wormser, F. E. (ed.), *The Marketing of Metals and Minerals*, pp. 588–89.

buyer and seller, the following points are commonly covered and should be studied closely by the prospective seller of ores and concentrates.

Duration and termination of contract.—A contract may be entered into for a stated period of years, or may remain in force until a certain tonnage has been delivered. If the latter form of agreement is made, a clause permitting the termination of the contract should be stipulated in case the miner finds it impossible to produce the required amount. If the smelter has obtained a profitable arrangement with a producer, it is naturally to the smelter's interest to perpetuate it; and the miner should be warned not to sign away all possibility of erecting his own treatment plant—or, worse still, to deprive himself of benefiting by improvements in metallurgical science by binding himself under a contract that will give the smelter all the gain from such improvements. Some provision for the termination of the contract should always be stated.

Subsidiary options.—Ore buyers often put forward for consideration a contract containing astutely drawn clauses giving them an option under certain circumstances to alter certain terms. Such options are nearly always in favor of the ore buyer. All documents should be searched for such subsidiary-option clauses, for it is quite possible that a short clause of that sort in an ore-selling contract might be of such a nature that a third party would not be justified, on this account, in purchasing the mine.

Source of ore.—It is usual to specify from which mine or group of mines the ore to be treated shall be taken, so that misunderstandings will not arise in case the ore seller acquires other mines.

Nature of the ore.—The costs of treating ores of varying proportions of metal content, and in treating various states of ore—raw or sorted, screenings, concentrates, or mixtures—will differ widely. It is therefore desirable to define the acceptable limits both for the percentage content of various constituents and for various states. However, it is also possible to arrange for the acceptance of any class or state of ore, fixing a smelting charge for each proportionate to the difficulty of treatment.

Quantity.—The contract should state within certain limits the tonnage to be shipped and the rate of delivery. If the total output of a mine is not under contract, provision should be made for some average quantity to be shipped, and the ore seller should be given the power to dispose of his excess or low-grade ore as he desires.

The stipulation as to the amount of ore to be shipped is designed to protect the smelter from being flooded during periods of high prices or having to reduce the efficiency of his plant when prices are low. The smelter must know within a small margin the amount he is to receive from each customer, so that his metallurgical arrangements may be maintained. If he is assured of a definite supply of ore, he can organize his plant to handle the products of his various customers on that basis.

The quantity clause is a just arrangement, and is usually enforced by cancellation of the contract or by penalizing the ore seller for extended failure to deliver the required amount.

Definitions of quantity.—Words used to express quantities should be defined in the contract. It should be stated whether the metric ton, the long ton of 2,240 pounds avoirdupois, or the short ton of 2,000 pounds avoirdupois is to be used, and whether dry or wet. When gold and silver are discussed, the ounce is commonly the troy ounce. The "unit" should preferably be defined as one per cent of a short ton, or 20 pounds avoirdupois. If the contract applies to a foreign producer, a clear statement of the system of measurement intended for use, metric or otherwise, is particularly important.

Place of delivery and shipping expenses.—The contract should specify where delivery is to take place—at the mine bins, the smelter, or some intermediate point. The smelting company usually assumes responsibility for shipment from railhead, however, and since it is an important customer, can frequently make better terms with the railways than can the individual miner. Sometimes the smelter is enabled to pocket a small profit on the shipping transaction by stipulating some point of delivery, such as railhead, rather than by taking delivery at the smelter and agreeing to deduct exact costs of freight and handling.

Overseeing shipments and keeping records will add to the management costs of the party responsible, who must arrange for cars, pay demurrage, check losses in transit, supervise loading and unloading, and, if the shipment is from a foreign country, undertake a great number of other operations, such as freight handling, customs, and insurance, connected with the transport of goods by sea and land from one country to another. All these items are to be considered part of the shipping charge.

The contract might also arrange for a diversion of delivery point in case the ore buyer wishes to send the ore to another of the

buyer's treatment plants, charging his account with any additional shipping expense.

Weighing and sampling.—Weights and samples are usually taken in the presence of representatives of both ore buyer and ore seller.

The method of sampling should be outlined with great care, describing how and by whom it is to be done. Enough samples should be taken to provide sufficient assay pulps for both parties and for use in case an umpire assay is required. The contract should state which party is to pay the expense of sampling and weighing.

Assaying.—The clause regarding assaying should be drawn to include the names of assayers and a complete description of the chemical methods to be employed in determining the content of all constituents mentioned in the contract as paid for or penalized. Assaying methods should be described in detail, giving procedures for standardizing the solutions and the fluxes used in these determinations. Both parties should have assays made. The ore buyer's returns are ordinarily used unless protest is made by the ore seller. Another method is to give "splitting" limits for each constituent; if the two assays lie within these limits, the average of the two is used as a basis for settlement. If the difference between the two assays exceeds the splitting limits, a third sample is sent for assay to an umpire, named in the contract, whose result is final. It is generally agreed that this result is to be the basis of payment if it lies between the assays reported by buyer and seller; if it does not, the original assay closest to the umpire assay is taken, and the party whose assay was farthest pays the umpire's fee. Such arbitration clauses may save litigation, and they are evidence of an intention to interpret the contract equitably.

Moisture content.—Since the ore or concentrate is weighed when it is wet and all assays are made on the basis of dry ore, it is most important that determination of moisture content be made with care. This determination is a difficult process, and therefore the exact method should be described. The taking of the moisture sample should be performed in the presence of representatives of both parties.

Penalties are usually imposed upon ore that exceeds a maximal percentage of moisture. The railroad is the only one that profits by the shipment of carloads of ore containing a large proportion of water.

Although stress has been placed upon the need for the ore seller

to protect his interests, it is sad to relate that the ore buyer must sometimes take precautions against deceit. "One enterprising shipper," it is said, "observing that the smelter people were in the habit of opening up the middle of the carload and excavating a short way toward the ends until a representative face was opened up, and then taking the moisture sample there, conceived the bright idea of turning the hose on the ore in the ends of the car while loading."[3] This practice caused the smelter to pay for the added water at the same rate as for the ore, but the deception was soon discovered.

Payment.—The time, place, and manner of settlement should be explicitly stated in the contract. The quotations used as a basis for payment must be clearly stipulated. The most extensively used quotations are those appearing monthly in the *Engineering and Mining Journal.* The date of the quotations used as the basis for payment may be date of receiving shipment; or the date of assay comparison, i.e., "cash" prices; or the "forward" quotation at a stated number of months after delivery date, to cover the period required to smelt the ore and market the product. There is a wide variation in custom in regard to this date of basic quotation. The most equitable arrangement would be for the miner to receive for his metals the same price as that received by the smelter, i.e., "forward" prices; but as full settlement could not be made at the time the ore was sampled, such a method would be inconvenient. However, a partial settlement could be then made, with final adjustment when the smelter had marketed the metal. In default of such an arrangement it would seem that the most equitable and convenient arrangement would be to accept the average quotation for the week of delivery; this would involve no delay in settlement and no calculation of average price over an extended period.

The contract should state whether settlement for all shipments is to be made on the first of each month, or settlement of each lot is to be made separately; whether settlements are to be made by cash payment to the owners of the product shipped, or to the owners' representative; whether payment is to be made by check or by draft; on what city exchange is to be drawn; and, if settlement is to be made in foreign countries, in what currency payment is to be made.[4] Foreign contracts should also mention the date and source of quotation to serve as the basis for exchange rate.

[3] Grabill, C. A., "Ore Contracts," *Engin. Min. Jour.,* Nov. 22 and 29, 1919, p. 810.

[4] *Ibid.,* p. 813.

Many smelter contracts have been drawn which increase the smelting company's profit during a rise in metal prices, thus making the miner lose all or part of the benefits of the rise. However, in a rising market the smelter has more opportunities to reap profits than has the miner, and there would seem to be little reason why his smelting services should be more heavily compensated at such times.

On the other hand, during periods of low prices allowance should be made for suspension of the contract. It will be shown in the following chapter that there is a minimal price at which metal producers must shut down. If the mine has a sound cash reserve it can continue to operate and store its product until better times; but it should not be forced to sell its product at a loss. The smelter may also be willing to shut down at such times; nevertheless, the suspension of deliveries during periods below a minimal price should be clearly provided for in the contract, by a so-called "stop" clause.

Taxes and demurrage.—Federal and state taxes on ore or metals purchased under the contract are usually charged to the ore seller. Demurrage on shipments, caused by factors beyond the control of the buyer, are also deducted from the seller's account.

Advances.—If advances may be secured from the buyer, the terms under which they may be obtained should be stated in full, giving whatever steps the buyer has the right to take to protect his interest.

Force majeure.—Suspension of the contract should be allowed in unforeseen circumstances, among which may be named strikes, lockouts, accidents, breakdown of machinery, floods, perils of the sea, acts of God or the government, war, or other disturbances beyond the control of either contracting party. This clause in the contract should state whether agreements are to be dissolved or suspended thereby, and, if the latter, whether the period of the contract shall be extended to include the time lost.

Succession.—Some legal provision should be made to assure the smelter that any transfer of title to the mine will not disrupt existing contract terms.

Storage.—In case of suspension of contract, the question ot storage of ore or concentrate will arise. Storage involves loss, expense, and risk, whether the product is stored at the mine or at the smelter. The ore buyer realizes such contingencies much better than the miner, and is generally alert to protect himself from loss or expense in such a circumstance.

Penalties and bonuses.—Penalties for failure to meet contract terms should bear equally heavily upon either party, be he buyer or seller. However, it is true that the ordinary contract will reveal that the ore buyer is fully protected by a system of penalties which the seller, by insistence at the time of signing the contract, could easily make mutually applicable.

Some contracts make a feature of bonuses. The object of the bonus is to offset some charge that would be too severe if applied indiscriminately to all ores. The bonus is also designed to stimulate the production of certain especially desirable kinds of product, or products of a certain quality. Ore buyers may thus use the bonus to induce miners to ship low-grade material, such as concentrate from a canvas-table, which material would otherwise have been discarded. The bonus may also be used to stimulate shipment of highly concentrated material, which can be smelted and transported to distant points at a cost much below what would have to be charged for the same amount of metal in a bulkier state.

Schedule.—The schedule is the heart of the contract. It should specifically state the method of calculating what is to be paid the producer for the desirable constituents in his ore, and what amounts are to be deducted for metallurgical losses and for the presence of undesirable constituents that add to the cost of treatment. The "smelting charge," representing the nominal cost of smelting the ore or concentrate, will also be stated in the schedule.

The figures that make up the schedule are those to which the seller must give most attention, for the customary statements are sometimes exceedingly involved and may contain clauses that will give the smelter a profit much greater than that to which his services would logically entitle him. When the prospective ore seller is scrutinizing the schedule and the various charges and deductions that it allows, he would do well to reverse the old maxim to become "Let the seller beware."

The smelting, treatment, or working charge, as it is variously called, may vary greatly from one contract to another of the same smelting company. Some ores and concentrates are so favorably composed that smelting costs are reduced to a minimum; but a low treatment charge does not necessarily mean that the ore seller is getting more return for his product than he would under a different contract—he may be paying in a variety of other ways the total amount that goes to make up the margin of profit to the smelter. Low treatment charges have frequently been used as a sales argu-

ment by a smelting company that makes its margin in other places on the settlement sheet. Treatment charges sometimes vary in proportion to the gross value of the metal content.

The schedule should describe in detail how certain substances in the ore or concentrate shall be paid for or penalized. The basic theory of payment for valuable metallic constituents is that the smelter will pay only for the amount of metal he can recover. He knows precisely what this amount is; but the miner can know only in a general way the percentage of recovery possible, and is therefore at a disadvantage. This situation commonly results in the signing of a contract so drawn that the smelter pays the producer for a recoverable quantity much less than that actually obtained, and the difference goes to swell the profits of the smelting company.

Marketing and refining charges against the smelted metal, usually made in the form of deductions from the metal price, are almost always so liberal that the smelter is fully protected and at the same time is able to make a concealed profit on these items.

The substances usually covered by a smelting schedule are gold, silver, copper, lead, zinc, iron, lime, silica (insoluble), sulphur, and undesirable substances such as arsenic, bismuth, and antimony.

Gold. The clauses in the schedule vary. Payment for gold varies from 85 per cent to 100 per cent of the assay, at a price of 80 per cent to 100 per cent of the current market quotation on a specified date.

This deduction is made ostensibly to cover refining and marketing. Some contracts stipulate a deduction for loss in recoverable content; but since the treatment charge is usually covered by another clause it is unjust to deduct for a metal that is known to be 100 per cent recoverable under modern metallurgical practice. Furnace recovery is almost always higher than assay recovery; and any such deduction will go to swell the smelter's margin of profit.

Silver. Payment for silver content varies from 50 per cent to 98 per cent of the market value, a greater variation than that for any other metal. Generally, 95 per cent is paid for, above a minimum of one ounce per ton; and frequently 3 or 3½ cents per ounce is deducted to cover refining and marketing expenses. It is likely that the smelter recovers more silver than the assay would indicate.

Copper. In contracts for the purchase or sale of copper ores or concentrates, the schedule usually states that copper contents, as shown by assay, will be paid for after .8 per cent to 1.3 per cent has been deducted; and after 2 to 4 cents per pound is deducted from the quoted market price to cover refining and marketing of the metal.

There are at least four ways of expressing deduction for loss in recovery, and some of these ways are subject to more than one interpretation.

1. Suppose the contract reads "one per cent deducted," and the ore assays 10 per cent. It might be thought that the proper arithmetical procedure would be to take 10 per cent of 2,000 pounds, or 200 pounds, and from this deduct one per cent, or 2 pounds, leaving payment for 198 pounds due to the seller. But this is not what the buyer usually means, though he may not have made the procedure clear at the time the contract was drawn. What he means is to subtract one unit from the assay value of 10 per cent, leaving 9 per cent, or 180 pounds, to be paid for.

2. "The zinc contents as determined by assay, less 8 units." A unit here means one per cent, and if the ore or concentrate contained 40 per cent metal, then 40 minus 8 per cent, or 32 per cent, would be paid for.

3. "Deduct 1.1 per cent of the copper contents." If the ore assayed 21 per cent copper, the copper contents would be 420 pounds. Deducting 1.1 per cent of 420 pounds leaves about 415 pounds of copper per ton to be paid for.

4. "Deduct .8 per cent from the assay." This phrase has many meanings that give rise to much contention; and the ore seller should be warned that the wording is misleading, and that it always means .8 *units*. He should obtain a written statement showing the sum the seller would receive on the class of ore he expects to ship.

Deductions from quoted price should specify whether "electrolytic copper," "standard copper," "London quotation," "New York quotation," "cash," or "forward" will be used as a basis. So many cents per pound, or an equivalent in other exchange per ton, may be deducted, or payment may be made on some percentage of the quoted price.

The ordinary statement that the basis of payment will be "90 per cent of the metallic contents at 90 per cent of the market price" could be more easily and clearly combined into a single, inclusive figure; that is, 81 per cent (or 90 per cent of 90 per cent) of the metallic contents at the market price.

Under the best modern practice, the loss in smelting copper is rarely more than .5 units; if the smelter is getting an allowance of 1.3 units in such a case, his profit will be .8 units on this item alone.

Lead. Although the usual lead contract allows for payment on 90 per cent of the lead content, anyone familiar with modern lead

smelting knows that such a percentage of recovery is decidedly low on ore of normally good grade. The smelter unquestionably makes a profit on such a figure. He may also deduct from 1 to 1.5 cents per pound for refining and marketing—another opportunity to make a hidden profit.

Lead in copper ore is sometimes recovered, but very rarely paid for, for the logical reason that copper-lead matte is costly to refine. Since lead furnaces require at least an 8 per cent metal content in the charge, payment for small amounts of metal in ores of low lead content are not usually allowed.

Zinc. Most contracts for the purchase of zinc ores read: "Payment will be made for the zinc assay less 8 units." If an ore assayed 50 per cent zinc, then 84 per cent of the metal would be paid for, while recoveries range from 85 per cent to 95 per cent.

In American tri-state contracts a base assay is mutually chosen upon which to calculate the amount of money to be paid to the producer. In the case of Missouri ores, this base is an ore assaying 60 per cent zinc. The *Engineering and Mining Journal's* statement that Joplin ores are quoted at $50 means that the buyer will pay the Joplin miner $50 per ton for an ore assaying 60 per cent zinc, and that $1 per ton will be added for each per cent the ore assays over this base, while $1 per ton will be deducted for each per cent under this base. This differential varies with the rise and fall in the market price of the metal.

When zinc occurs in lead or copper ores it not only is not paid for but moreover is penalized if it occurs in excess of 5 to 10 per cent. There are sound metallurgical reasons for such penalization.

Iron and lime. Iron in a lead ore is generally paid for at the low rate of 10 cents per unit, and lime is sometimes allowed for at the same rate. These two materials have a fluxing value to the lead smelter, and if some ores contain an attractive proportion of either or both of these fluxes he may be justified in paying more for them, since he might otherwise have to mine or purchase these necessary constituents of his smelter charge.

Silica, or insoluble. Nearly all American contracts exact a penalty on silica, ranging from 10 to 20 cents per unit for each unit above a certain percentage, usually 8 to 10 per cent. However, since silica is an essential component of a smelter charge, the smelter may be combining ores from two different mines—one low in silica content, and one high—and thereby obtaining a suitable average percentage, meanwhile charging one producer for deficiency in flux-

ing content and charging the other producer for excessive silica. Such an opportunity for the smelter to butter his bread on both sides is seldom overlooked.

"Insoluble," in addition to silica, includes such substances as alumina, fluor spar, barite, and garnet; these, although not always undesirable, are sometimes penalized.

Undesirable constituents. Other elements in ores that complicate smelting procedure and increase expenses are properly penalized. Among these are arsenic, bismuth, and antimony, as well as cobalt and nickel when they are found in lead or copper ores. Although some of these elements may be recovered the expense of doing so is not usually justifiable.

Sulphur. In lead smelting, sulphur is undesirable and raises treatment costs; but if this expense has been included by the smelter in his treatment charge any penalties may well give a hidden profit to him.

On the other hand, a certain proportion of sulphur is necessary in copper smelting, and when a quantity is present that does not exceed the desirable maximum, it should never be penalized; in some places it might justly command a premium. If the excess sulphur in the ore is utilized for making sulphuric acid, a fair part of its value should naturally be credited to the account of the producer.

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Chapter 10

Metal Prices

For many years the only price figure used in valuation was the long-term average selling-price of the metal. Up to the time of the World War this long-term average seemed to be a fairly safe basis; but so useless have developments of the past two decades proved this method that a deeper understanding of price variations is required of the engineer if he is to state intelligently the probable success of a mining enterprise. Even though all other computations of value are made with exactitude, a slight overestimation of price to be received for the product will be sufficient in itself to vitiate the engineer's conclusions.

For this reason the engineer should protect himself by stating in his report the price or prices upon which his calculation of future revenue from the property is based, thus allowing his client to understand clearly the variation in value that may result from a rise or fall in market prices of the metals recovered.

THE FUTURE OF GOLD PRODUCTION

The Director of the Mint estimated in 1931 that more than half of the total world production between 1492 and 1930 has been mined since 1900. It is obvious that the gold mines of the world cannot long keep up this pace. The peak of gold production has probably been nearly reached, and sometime in the dim future there will be a decline in the annual production; the decline will probably be slow and gradual, allowing time for adjustment of world economy to the changed conditions.

This unpleasant fact, a diminution in the production of the world's standard of value, must be faced by economists and statesmen in the decades to come. The consequences of such a situation will be many and serious. They may result in conditions that mankind has never experienced, and about which one can only hazard a guess. But the first effect will obviously be a gradual decrease in the price of all other commodities measured in terms of gold.

The peculiar position of the gold miner, as producer of a product with what is normally a fixed price, is a curb on the energetic exploitation of gold-bearing deposits. The rise in prices of commodities increases the cost of carrying on all business. In most industries, increased cost can be neutralized by increasing the price of the product, but as gold in the United States still has a fixed price the gold miner in this country is barred from attempting to recoup his higher cost by putting a higher price on his product. All major upward variations in price of other metals, as has been pointed out in an excellent article by L. C. Graton,[1] tend to increase known reserves, and a rise in price brings a direct increase in actual output. But gold experiences no such influence. In times of general prosperity commodity prices are high and the cost of gold mining is therefore high; the purchasing-power of the gold produced by the miner is curtailed (see Fig. 6); and the margin of profit is small. On the other hand, when the business cycle suffers a depression, the gold miner cannot benefit as much as he should by lowered costs of production but is likely to fall partial victim to the pessimism of the times and to find difficulty in obtaining capital for his enterprises.

The economic and political importance of insuring a steady stream of gold from the mines has been recognized by the nations of the world at various times, and gold-mining is already a favored industry in many countries. It is not inconceivable that at some time in the future it will be no uncommon practice for governments to have recourse to the payment of some form of bonus—as did the British government during the World War—to encourage the search for gold-bearing deposits and the operation of low-grade mines.

Influence of gold production on prices.—One school of economists holds that prices depend greatly on the annual production of gold; and it is true that for long periods the price level has paralleled the gold supply curve. But the annual production of gold is small in comparison with the monetary stocks of gold held by the leading nations, estimated by the Director of the Mint to amount to $9,277,622,000 in 1925. An annual world production of $375,000,000 (average 1920–1929) would be only about 4 per cent of the total accumulation. Even if gold production varied somewhat from this proportion, it is hard to believe that this would

[1] Graton, L. C., "Future Gold Production—The Geological Outlook," *Trans. A.I.M. & M.E.*, 1931, pp. 534-57.

influence prices to any great extent. It must be admitted, however, that entire cessation of gold production, or even a very marked increase, would be reflected in the long run by a change in commodity prices.

Since the second edition of this book was issued a startling new factor has been introduced into the gold problem. This cannot be ignored in any symposium on the economy of metals. Early in 1933 Congress passed, and the President signed on April 19, a bill which outlawed all gold payment clauses in money and public and private contracts, and enabled the President arbitrarily to set the price of gold at any figure he pleased.

Although in earlier editions of this book an increase in the value and price of gold due to natural causes had been foreshadowed, this legislation, operating in the same direction as the natural causes, brought about less dislocation to our economy than might have been expected. This drastic upheaval in financial morals now appears unnecessary. It was a rash political maneuver and its final result will probably be the hatching out of a flock of economic vultures which will ultimately come home to roost.

Just what this maneuver meant to the American people may be shown by very simple arithmetic. Prior to 1933 if you owned a $1,000 gold bond you would, upon presentation at maturity, receive, if you demanded it, $1,000 in twenty-dollar gold pieces. These gold pieces would weigh almost exactly 48 ounces. After 1933 when you presented the bond for payment you received $1,000 in paper money, but no gold, and if you wanted to take the risk of a term in jail you could, with this $1,000 in paper money, buy gold in Canada at the rate set by the President—$35 per ounce. The $1,000 in paper money you received for your bond, divided by $35 per ounce, would enable you to purchase almost exactly 28 ounces of gold. In other words, 20 ounces, or $400 of your savings had been juggled out of your pocket by this hocus-pocus.

FUNDAMENTAL CONCEPTS

A glance at the shelves of any large library will show an appalling number of books on finance and economics, expressing a bewildering variety of opinions. In order to avoid complications it seems best to define a few terms that are necessarily used in the discussion of metal prices.

Price.—The amount of money asked or given in exchange for anything is termed its price. Since the monetary standard of the civilized

world has been based on gold, however, it is preferable to use in place of "price," when discussing gold, some such term as "purchasing-power." The gold miner has found that its purchasing-power has varied from \$1.47 in 1914 to \$0.65 in 1920 (taking 1926 as a base), increasing as the price of other commodities dropped and decreasing as these prices rose (see Fig. 6).

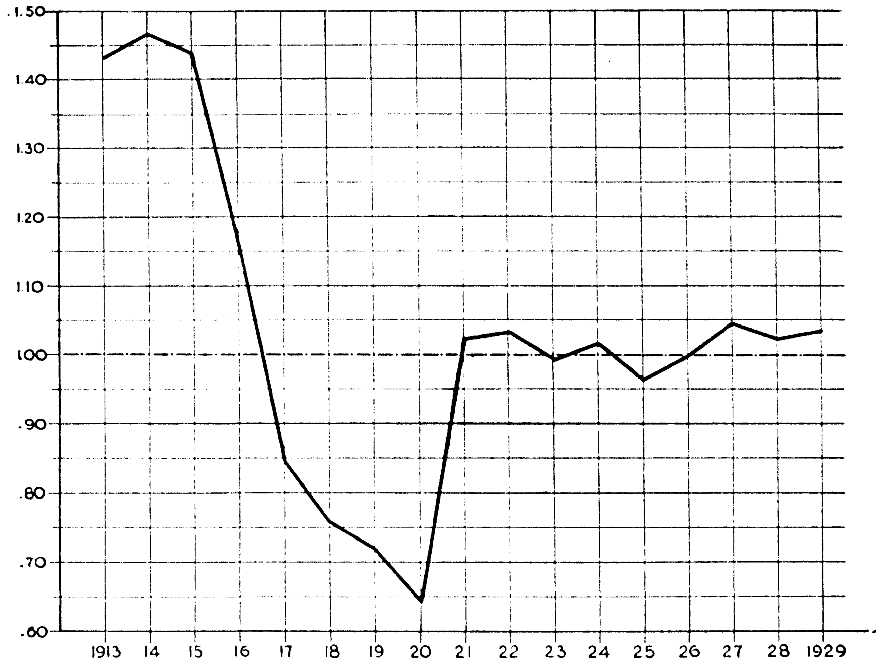

FIG. 6.—Changes in Buying Power of the Dollar in Purchase of All Commodities at Wholesale (1926 = 100.0)

From "Wholesale Prices," *U.S. Dept. of Labor, Bureau of Labor Statistics, Bulletin 521*, 1930, p. 71.

Money.—Although everyone knows what money looks like and how hard it is to obtain and retain, it is not easily defined from a world-wide point of view; for money varies in its concrete form, as a means of storing surplus wealth, from the brick-tea used in northern Asia to the water-worn boulders used in the island of Yap. In all places where barter does not prevail some commodity has at one time or another become a standard of value, and these have included cowrie shells, salt, tobacco, cocoa beans, cattle, and hides, as well as certain metals. Money is therefore anything used as a medium of

exchange or measure of value, or simply as a measure of value. Confining this definition to the markets of the United States, it is the legal currency represented by the familiar bank notes and metallic coins.

Standard of value in the United States.—The monetary standard of the United States was originally based on the dictum of Congress in 1792 that 270 grains of gold, 0.916 2/3 fine (equal to 247.5 grains of pure gold), shall be stamped $10. This continued to be the standard of value until 1933, when the weird legislation referred to on page 184 went into effect. Now the standard is a shifting figure, around $35 an ounce. That the monetary unit may be a measure of value although not acually circulating as a medium of exchange is shown by the fact that the gold dollar, which is the unit in this country, is not coined at all because it would be too small for convenience. It is also known by the fact that for fourteen years there has been no gold whatever in circulation.

Although gold has been the accepted standard of the great industrial nations of the world, it is by no means a perfect standard, for the amount of gold annually produced bears no steady relationship to the increase in population and the needs of commerce. It seems probable that the world production of gold will shortly start on a steady decline, yet the monetary needs of the world are steadily increasing; this brings an expectancy that the purchasing-power of gold will rise indefinitely, unless there is some readjustment of the amount of credit which may be based on a given stock of gold. Such inflation of the gold unit by legislative action is possible, but it is limited by the degree of confidence held by the public in the legitimate uses to which that credit is put. Any legislative measures attempting to adjust the flow of gold and the size of reserves must be aimed at the greatest possible stabilization of the purchasing-power of currency.

Various substitutes have been suggested for gold as a standard of value, but none of them has been widely accepted by students of finance. Among the proposed substitutes are: (1) the tabular, or multiple standard, which is virtually the index number; (2) wheat, which has been discredited by its extreme fluctuation in value during the past few years; and (3) the day's work of an unskilled laborer. The great difficulty in establishing a standard of value is to provide for deferred payment that will give no unfair advantage to either debtor or creditor and will in general prevent the shrinkage of the

purchasing-power of a fixed income. No practicable plan for the standardization of value in deferred payments has ever been devised.

Price level and index numbers.—The general level of prices is the combined average price of all the important commodities at that time, and is commonly expressed by an index number. Various index numbers are used by economists in the study of price variations. An index number is the relative price at a given time in terms of the price at a previous date chosen as a base and fixed arbitrarily at 100. In order to be truly representative of general fluctuations in price an index number must be made from a large number of commodities weighted in proportion to their significance. The use of such an index number will reveal changes in relative value of the monetary standard and of goods in general; but it will merely show the change, and will not indicate whether it was caused by the shifting of value of this standard or the shifting of value of the commodity. As will be suggested, the causes of changes in value are among the most complicated phenomena of economics.

Figure 7 shows the price level between 1890 and 1929 expressed in index numbers with 1926 as a base. Two curves are given, one showing a weighted index for wholesale prices of all commodities, and the other showing a weighted index for prices of metals and metal products. The price at a given year relative to all other years can thus be readily seen.

The price level is reciprocal to the purchasing-power of money; that is, when the price level is low, the purchasing-power of money is proportionately high, and vice versa. This may be seen by comparing the curve in Figure 6 with the price level curve in Figure 7 for the period 1913–1929.

When the price level is low, the prices of all the commodities it represents are, on the average, also low; in other words, as the purchasing-power of gold increases the average price of commodities decreases.

Normal price.—This term has been used to designate the average price during a long period; but it is a misnomer, and it is much better to call it what it is, merely the "average price."

Base price, or basic production cost.—There is a minimal market price for each metal below which it cannot fall without putting the average producer out of business; this price has been called the "base price." An alternative term is "basic production cost." It costs a certain sum to produce a pound of copper; if the price falls

below that minimum, most of the copper mines must shut down when their funds are exhausted. The cost of producing copper or lead or zinc is not the same for all mines, and not all will be forced to shut down at the same minimal price; but there is an average production cost which will force many of them to shut down when a low market price is reached, so that the decreased production thereby occasioned causes, within a brief time, a shortage of metal and thus the pendulum of oscillating metal prices swings the other way. The base price for each metal may be calculated with considerable accuracy.

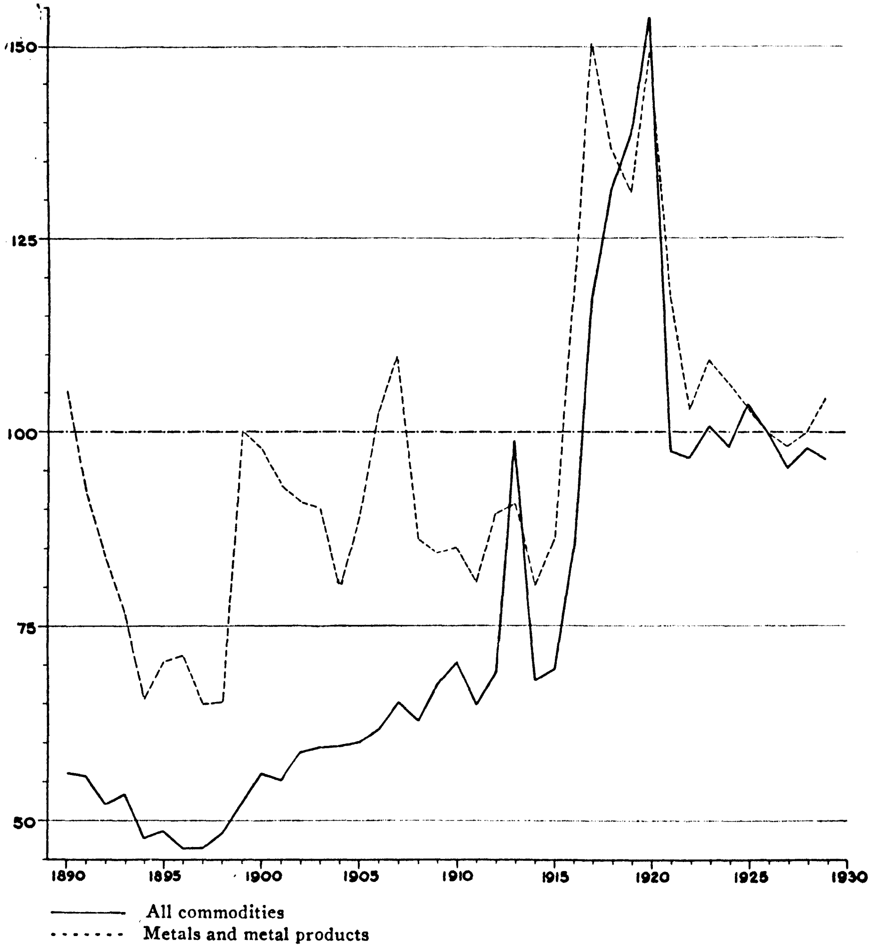

FIG. 7.—Index Numbers of Wholesale Prices, 1890–1929 (1926 = 100.0)

From "Wholesale Prices, 1929," *U.S. Dept. of Labor, Bureau of Labor Statistics, Bulletin 521,* 1930, p. 12.

Supply and demand.—The supply of and the demand for a commodity determine its price, and, as these vary, so prices vary. As the demand of consumers increases, the commodity becomes more desirable and the price rises; as the price rises, the rewards of production are greater and a greater supply is produced; as supply increases, it eventually exceeds demand and the price drops.

Monopoly vs. competitive prices.—In the long run, the price of metals is fixed by the law of supply and demand. This implies competition between producers of the same or an equivalent product. Under free competition the current price for a product is fixed at a single figure; if there were more than one price, no buyer would purchase at the high price and no seller would sell at the low price. There is, however, a slight lag in the reflection by prices of supply and demand at a given moment, due to the imperfections of communication.

However, under some conditions free competition does not prevail, as when attempts are made to fix an arbitrary price by obtaining a monopoly on the product, either by "cornering" the supply of the product as it comes on the market, or by securing possession of the entire source of supply. The price set by the monopolist will not be determined in the same way as the price under competition; he will aim to secure maximal return without killing sales, and this psychological price is arrived at by trial and error.

FLUCTUATIONS IN PRICE

Metal quotations.—The greatest metal market in the world is in New York City. London is second in importance, and has a recognized metal exchange from which an official quotation may readily be obtained. A metal exchange was established in New York in 1883, but no sales are officially transacted on it and its quotations are not recognized by traders; it is really an exchange in name only, and the most reliable statistics of metal buying and selling are records of transactions published in the press. Of these the quotations given monthly by the *Engineering and Mining Journal* are standard for non-ferrous metals. These figures are the nearest approach in this country to official quotations; they are widely used as the basis of current and future selling in contracts and have been recognized in the courts and by the government.

This periodical interviews at certain intervals all important producers and consumers of metal supplies and obtains confidential information concerning date, quantity, delivery, and price on all transactions. From these data, weighted in accordance with the size of the transactions, the average quotation is obtained. "If, for example, a producer one day sells 10,000,000 lb. of copper at 19¼ cents and on the same day 100,000 lb. is sold in the outside market at 18⅞ or at 19½ cents, as the case may be, the average is changed very slightly above or below 19¼ cents. Yet 18⅞ or 19½ will be the 'outside market' quotation."[2]

These quotations have been severely criticized by some of the other technical journals, and naturally such a method places much responsibility upon a single trade organ; but the figures given by this authority are the best obtainable and have stood the test of many years of use.

Price fluctuations.—When metal prices are charted it will be found that the curve rises and falls spasmodically. These fluctuations are more pronounced if short periods of time are used; if the curve is smoothed, it will take the form of a series of cycles representing the operation of supply and demand. Further smoothing will make the curve for each metal commodity approach a closer relationship to the general price level.

Estimation of future prices.—As has been said, the forecasting of future price is dependent upon so many factors impossible to weigh or anticipate that in recent times estimating is almost reduced to a hazardous guess. The causes of fluctuations are innumerable, and when any marked movement of price quotations begins there is no way of knowing how far the rise or fall will extend. The use of price curves as a basis of forecasting will as often as not lead to faulty and disastrous conclusions, unless full consideration is given to the various factors that determine the course of these curves. The producer who does not allow a margin of profit great enough to protect himself against a prolonged period of low prices may find himself forced out of business.

Although no attempt can be made here to evaluate the various causes of price variation, it may be worth while to discuss a few of the most important of these for the information of the young engineer.

[2] "The Price of Metals," (edit.) *Engin. Min. Jour.*, Feb. 14, 1920.

CAUSES OF PRICE FLUCTUATION

Cycle of production.—The effect of the familiar operation of supply and demand upon price changes is shown by considering the interaction of market price and production. High prices stimulate production; then, when the supply thus created exceeds demand, prices fall. If prices fall below production cost for a period sufficient to eat up the financial reserves of the producers, they must shut down their mines; supply falls off, prices rise, and the cycle begins anew.

Overproduction is the bugbear of the metal miner, and the instability of production caused by price fluctuation is one of the most disturbing influences in the industry. When prices are high, producers' supplies are usually small, and users, fearing a shortage, carry large stocks. When prices are low, users ordinarily are overstocked and trade is bad; they do not fear a shortage and hence the lowered demand causes still lower prices, until trade expansion and a revival of business reduces stocks of metals and price swings upward. When this time comes, mines that have long been shut down open again, and the high price stimulates overproduction of metal, which at length cannot be absorbed by the using industries. The difficulty is that the machinery of opening and closing a mine is too expensive and too ponderous to be adjusted to the fluctuations of the market. The operation of a mine is subject to a certain inertia that makes it almost as difficult to shut down, once it has begun production, as it is to reopen after a long period of idleness. After a mine has been shut down during a period of unprofitable prices it takes some time for the spur of higher prices to result in actual production. Directors and managers must assure themselves that times are propitious and that a reasonable period of operation is assured; supplies and labor must be gathered; the plant may require a capital outlay for overhauling and improvement—and often the crest of high prices has been passed by the time the new metal reaches the market. Then, having commenced production, the directors are loath to shut down again; they hope for an early recovery, and may even delay until an empty treasury forces the issue and they must shut down.

Lowering of production cost.—Any factors tending to lower production cost will also influence the market price in the same way. Widespread decrease in wages, cost of supplies, and other expenses; discoveries of greater, richer, or more cheaply workable deposits;

sweeping advances in metallurgical science—any extensive lowering of production costs caused by such occurrences will be reflected in a general drop in prices in a competitive market.

The New Jersey Zinc Company could at one time have produced zinc at a profit during periods when low prices would have shut down all the other zinc mines in the world. This mine was exceptionally favored in its supply of ore, metallurgical treatment, and situation near the market. The Burma Corporation in the Northern Shan States of Burma would probably continue to produce lead at a profit when almost all the other lead mines in the world were closed down. Here is a rare combination of rich ore, cheap and efficient labor, and a fairly large local market. The African copper mines would probably be able to undersell all other competitors in the copper market if required; here the favorable elements are large and rich orebodies and simple metallurgy.

The discovery and development of large and rich ore deposits, such as those of the Belgian Congo and Rhodesia, is the greatest single factor that can lower the production cost, and hence the price, of a metal. But as time passes and the earth's surface is more and more completely prospected, the chance of discovering any enormous metal deposits now unknown is greatly lessened.

Another possible cause of drops in future production cost might result from metallurgical invention and improvement, although the margin of improvement for several metals has been much reduced by recent advances. The valuation of any mining project may be rendered erroneous by the advent of new metallurgical processes or apparatus. There is a possibility that epoch-making developments in metallurgy will in the future profoundly alter, for some metals, the market prices predicted from present conditions. For example, the invention of a simple and cheap process for extracting aluminum from granitic rocks would inevitably be reflected in the market price of this metal.

Annual production.—The annual world production of a base metal does not show any close relationship to the price curve from year to year. For example, during the period 1897–1931 the curve of world copper production shows a fairly steady rise at an acceleration of about 5 per cent a year, while the price of copper oscillates in unsteady cycles of high and low. As in the case of gold, the annual production is small in comparison with the world supply that may be drawn upon if exorbitant prices stimulate conservation and also bring forth the threat of using substitute metals. No steady rise in

price of any metal may be expected until that more or less distant period when it is discovered that the peak of production has been reached and world supply is steadily diminishing.

World supply.—Since the great world reserves of most of the precious and non-ferrous metals are probably known at the present time, within reasonable limits of accuracy, it is doubtful if any new districts opened in the future will materially lower production cost. Moreover, whatever the world resources of a metal may be, it is a truism that every ton extracted will reduce that supply, and the world is faced with a diminishing stock of the metals upon which civilization is based. It therefore follows that the conservation of metal resources, as outlined in chapter 1, is an imperative duty of all those who desire this civilization to endure.

World demand.—While world supply diminishes with every ton mined, the observer need only look about him in order to realize that for many decades to come the industrialization that is advancing at an accelerating rate in Europe and the United States, and will in due course advance elsewhere, must require greater and greater quantities of metals to support it—not only the base metals used in construction but also the monetary metals that must serve as a basis for financing all its operations.

Although the valuable properties of metals are not lost when put into use, the amount available for re-use is not great; even iron, it is estimated, is lost to the world through corrosion and waste at the rate of one-third to one-half of annual production, while almost 80 per cent of the annual zinc production is used industrially in a form not reconvertible as secondary metal.

Not only will the established industrial nations require metals but the greater part of the world is still a fertile field for industrial advance. The vast Orient, Latin America, and Africa will steadily require greater and greater quantities of metals, base and precious. Indeed, for years the Asiatic nations, China and India in particular, have been bottomless pits into which has poured a large part of the gold and silver of the world's mines. This store of precious metals is buried or made into ornaments, and does not circulate in trade or form the basis of banking credits. Unless these peoples eventually change their habits, this hoarding of gold and silver cannot but result in a diminution of world supply, and the increased demand that will follow will so heighten purchasing-power that serious interference with present systems of money and credit may be expected.

Corners.—A corner is a monopolizing of the marketable supply of a commodity through purchase for immediate or future delivery. It is generally undertaken by a secretly organized combination for the purpose of raising the price. Attempts to corner the supply of a metal that is widely distributed have so far invariably been failures.

In 1889 and 1901 powerful efforts were made by different parties to corner the copper market. In 1888 a Frenchman, M. Secretan, fancied that the phenomenal development of electricity had resulted in a consumptive demand outstripping the capacity for production. He was correct in his hypothesis concerning demand, and if he had not miscalculated the volume of invisible stocks of copper in private hands, and the quantity of scrap metal that would be collected under the stimulus of high prices, he would have been able to put the price sky-high and keep it there until he had disposed of his stock. But there were large stocks in private hands, and every small boy hunted old copper kettles; M. Secretan could not hold the price up long enough to sell his huge stock of metal at great profit. It took his bankers several years to market his mountain of copper.

In 1901 the Anaconda Company attempted to stabilize the price of copper at a high level; its plans were upset by the energetic production of smaller producers who virtually forced the Anaconda Company to acquire a huge stock of its competitors' copper in order to maintain its price. The attempt collapsed, leaving the company with a supply of the metal more than enough to satisfy world consumption for three and one-half months.

Some hint of an impending fall in metal price may be gained by a critical examination of accumulated stocks; but these stocks may not all be visible, and any mathematical attempt to forecast the metal market may be upset—as were the efforts mentioned above—by the invisible stocks in the hands of manufacturers and in old metal, and by the potential new production stimulated by the high prices which result from the efforts of those forming the corner.

Monopoly of sources of supply.—Fulminations against monopolies of metal supplies are part of the stock speeches of anti-capitalistic agitators. At various times attacks have been made upon interests controlling a large part of production, but few metals, and mostly those in little demand, are under the single control of persons with power to fix monopoly prices.

It is stated that more than 90 per cent of the world's supply of vanadium is in the hands of an American group; but the value of the

annual consumption of this rare metal is insignificant compared to the value of such metals as copper and lead.

The world bismuth market is controlled by a London company that is able to fix a price for a period of months; the production of nickel has also been controlled by co-operative interests able to peg prices. At various times it has been claimed that foreign companies, often as part of the policy of their governments, have controlled supply and prices of nitrates, potash, mercury, iodine, and cobalt. For years a large-scale monopoly obtained in the control of the diamond supply by the principal mines of South Africa to keep the price at an unjustifiable figure; and this still obtains, although the forced sale of many gems after the World War, as well as outside production, upset the market to some extent.

The Aluminum Company of America has a virtual monopoly in the production of this metal in the United States, principally by reason of the control of processes in the early years of its establishment, as well as by control of the world's largest deposits of the bauxite from which it is made and of the cryolite used in the process. The Federal Trade Commission investigated its alleged attempt to restrain competition and to maintain a monopolistic price and the charge was dismissed in April 1930.

Numerous attacks have been made on the United States Steel Company as a monopolistic agent in this country; but these attacks are unfounded. The independent companies produced in 1913 about 56 per cent of the pig iron; in 1918, 60 per cent; and in 1930, 60 per cent.

Monopolies may necessitate strong and unscrupulous measures against possible competitors, as well as corrupt control and administration of an industry; but under certain conditions, especially when supply greatly exceeds demand, some form of central control will prevent cutthroat competition and act as a conservational force. Fear of government regulation or outside competition usually sets a monopoly price at something less than the traffic will bear. Regulated monopolies, including many of the public utilities corporations in this country, are perhaps the most economical form of organization known. That the right of free competition, as guarded by anti-trust legislation, is not sacrosanct is shown by the fact that the adoption of tariffs by various competitor nations is in reality discrimination in restraint of the normal operation of supply and demand. Offensive as well as defensive tactics against other nations also seem justifiable to lawmakers. "The Webb Act," to quote an

editorial in the mining press, "provides that American exporters may form a combination immune from the provisions of the Sherman anti-trust law against similar internal combinations, and may form a monopoly if they can, and fix prices and limit supplies if they can."[3]

A price fixed at a profitable level may be desirable from the points of view of both producer and manufacturer, for one element of risk is thereby eliminated and they can plan operations with more assurance.

Combinations to limit production.—Attempt to stabilize price by voluntary co-operation among producers has been made at various times when it was thought that overproduction was causing a ruinous drop in prices. The zinc producers of the Tri-State district have at times limited their output of zinc ore in order to raise the price of the metal, or to keep it from falling. The most impressive of recent attempts is the "gentleman's agreement" between American and foreign copper producers to restrict production and to refrain from encroaching upon each other's markets. Few will argue that such an arrangement is a monopoly to send prices up to unjustifiable heights; rather is it a protective measure to avoid cutthroat competition, to prevent loss and unemployment in an important industry as a result of a slump in demand and in prices, and to enable the orderly distribution of an enormous stock of metals created by uncontrolled production.

Recently there has been a marked effort on the part of governmental agencies to encourage producers to co-operate in restricting ruinous and wasteful overproduction and cutthroat competition. This is occurring in industries as varied as petroleum and agriculture, and incites them to put their house in order under threat of government intervention. Some form of check on overproduction, when controlled by those best informed in the industry—curbing though it may be to individual enterprise—is desirable if waste and uneconomical price wars are to be avoided. It may be noted that in the interesting case of the copper producers previously cited the limitation aimed at was not complete, as certain of the producers refused to co-operate. In nearly all of such attempts toward rational control there seems to be an irrational minority which succeeds in wrecking the control.

[3] "The Right to Restrict Output," (edit.) *Engin. Min. Jour.*, Jan. 23, 1926.

War.—As one might expect, war, or even the prospect of hostilities, has a most unsettling influence upon the curve of metal prices and tremendously enlarges the realm of conjecture upon future price. The first years of warfare are marked by an extreme climbing in price of metals above the general price level; but the effect of possible developments which may follow—such as bankruptcies, curtailment of production, and the rising and falling of the tide of victory—will be incalculable. About all that can be predicted is that the outbreak of war will send metal prices to a peak within a short time and that later prices will be marked by extreme variability in relation to the price level. For example, the price of copper during the closing year of the Civil War in the United States dropped from 30 cents to 17 cents, the high and low prices of a sixteen-year period, although the index number dropped only from 110.7 to 107.4 during that year. It is to be expected that in the present mechanized age the typical curve would be somewhat different. The influence of war, as well as other factors such as attempted monopoly, on the price of copper is shown in Figure 8 (p. 198).

Added to all these uncertainties is the wartime perplexity arising out of bungling methods of price fixing and tinkering with the currency. These factors defy evaluation or estimates. A good deal could be done to ameliorate many of the disturbances of war by a sound system of stock piles for war purposes.

Tariffs.—Tariffs, as has been suggested, may profoundly affect metal prices. Additional risk is introduced into the problem where the value of a mine depends upon an enhancement in price of metal by protective legislation. Government tariff regulations are not immutable, and changes may suddenly come that will wipe out the producer's profit completely. For many years the copper mines of imperial Russia were protected by a duty of six or seven cents a pound; when the revolution swept this away, many of these mines could not have been operated at a profit, in competition with imported supplies, no matter what the later form of government might have been.

Other influences on price.—Foreign buying will often elevate the price in the country of origin much above what should be considered a fair price under normal conditions. Heavy withdrawals of stocks from America may give the American market a rise in times when stocks are normal or low. Large orders from India and China are likely to occur together, creating a temporary but acute demand.

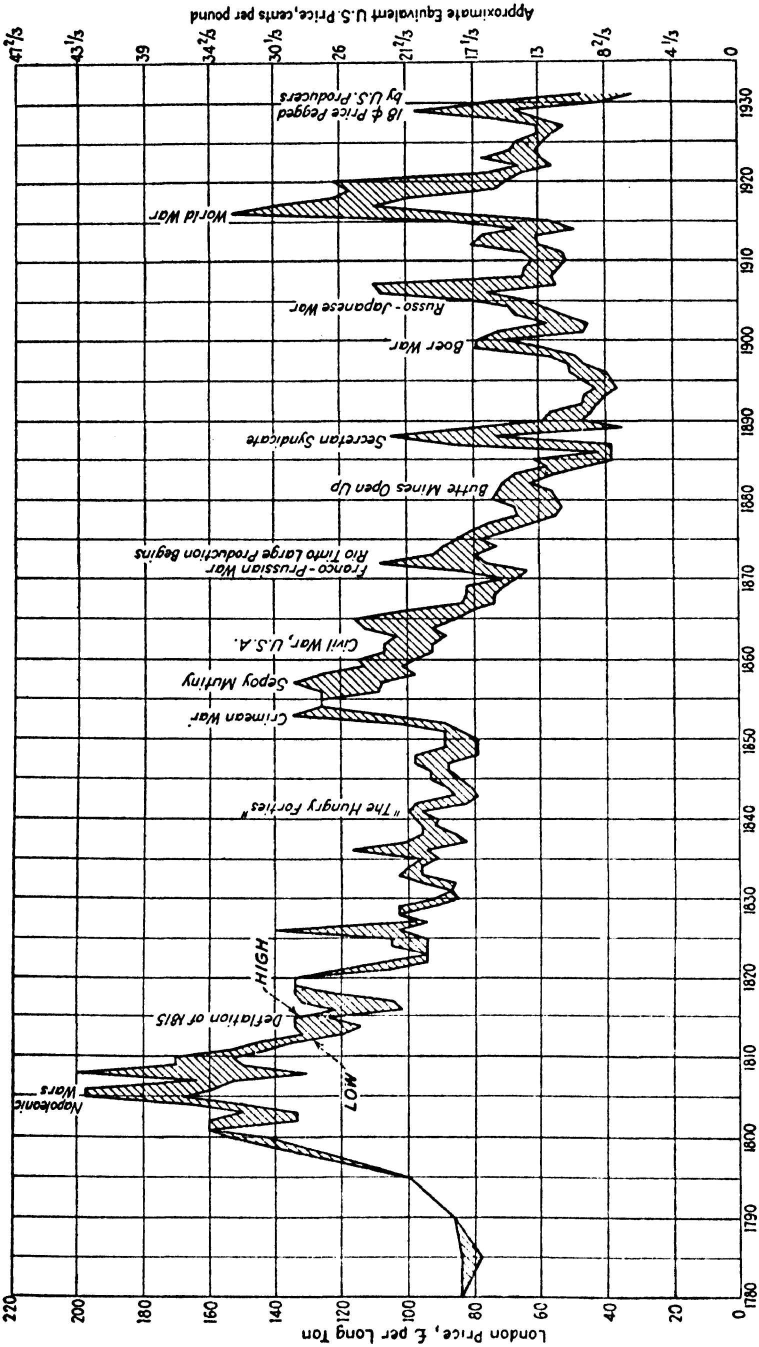

FIG. 8.—Factors Influencing Changes in Prices of Copper

(Reproduced by permission from *Mineral Industry during 1930*, page 734, "Long Period Graphical Metal Prices," by Percy E. Barbour)

Large government contracts, usually let at stated intervals, may cause a considerable increase in prices if other conditions are favorable.

The underlying strength or weakness of the metal market may at times be judged by the size of current buying orders, by the relation of sales records of the large companies to their production rate, and by deductions from published statistics giving production and consumption figures. Statistics will sometimes reveal an increase in stocks when the market is already weak; the drop in such case is sudden and sure. Official publication of production and consumption statistics will often enhance or depress prices far beyond any justification from actual supply and demand, as will statements by prominent authorities or government officials.

Curious lulls occur in the buying of manufactured articles, leaving the manufacturers with large stocks of their wares on hand. At such times they cut down their purchases of raw metal and thus a slackening in the purchase of manufactured goods is communicated to the metal market.

Holidays permit stock-taking, and the results may be reflected in a marked shift in buying and selling that will affect prices.

FUTURE PRICES OF NON-FERROUS METALS

Estimating future prices of non-ferrous metals, guided only by past records and quotations, is an impossible task, especially in times of market disturbances such as those since 1929. But the engineer is faced with the need of considering all factors bearing on the point, applying the engineering method, and "sensing" what may be a reasonable maximal and minimal future price for valuation purposes.

All the information that is available for predicting future prices of metals is the history of past price fluctuations and the present industrial outlook. How far astray intelligent writers and executives may go in predicting metal prices is seen in the prophecies of many financial experts who predicted 30-cent copper as soon as the war was ended.[4] According to the opinion of a conference of mine managers at Calumet, Michigan, held in October 1918, the great era of reconstruction was to bring the greatest prosperity ever known to the miners of copper; and it was felt that the price of copper would go sky-high unless a price limit was fixed. At that time

[4] *Engin. Min. Jour.*, Oct. 26, 1918, p. 766.

copper was 26 cents, almost the crest of recent years, and the high point preceding a fifteen-year decline.

All that can here be attempted is to make a few observations on some of the factors influencing the price of the more important metals in the future, taking a long view rather than seeking to predict prices for the next few years.

Silver.—India and China absorb silver as a sponge soaks up water. Millions of ounces have entered their ports and have been hoarded or converted into ornaments. These countries are now in a disturbed state, and prices for their chief products are low. When stability is restored and prices for these products improve, the resulting prosperity will again give the natives opportunity to indulge their racial trait of hoarding silver, if hoarding is still the fashion and they have not learned meanwhile to put their faith in banks. Silver is the "balance of trade" import in the coolie countries, and when trade is bad they must go on short rations of silver, thus hitting the silver producer. For this and other reasons, the supply of silver, which is produced largely as a by-product of lead and zinc mines, will probably be in excess of demand for some time to come, unless important new uses can be found for the metal. Only moderate prices for silver can be expected.

Copper.—The steady increase in the use of copper in industry, especially in the electrical trades, and the great actual and potential expansion in man's use of electricity, would seem to presage a growing demand for copper.

The supply at present is far from unlimited. New mines will probably be opened up; for example, there is some likelihood that the copper-bearing deposits in Canada may be found to equal the deposits of the Lake Superior region. In recent years some large copper mines have been brought into production, and few large mines have been exhausted.

War needs and the ensuing industrial expansion raised the demand for copper, and although the present period of depression and lack of vision and co-operation among producers have caused large surplus stocks and low prices of the metal, a good copper market in the future is to be expected. Not only is the potential use of this metal very great but many of the larger mines are getting old.

Lead.—The supply-and-demand ratio for lead would seem to have reached a fair stability. Its increased use would probably be balanced by discoveries of new reserves. Since the recovery of secondary lead

is not large, new production would only balance irrecoverable consumption losses and thus tend toward stabilization at a profitable level of price.

Tin.—The tin supply would seem to be diminishing. No new deposits of even moderate size have been discovered for many years. The demand is increasing, and it is reasonable to expect a gradual rise in price until, as the present deposits are worked out, the price rises as high as competition with substitutes will permit.

Zinc.—Zinc has been through troublous times, caused in the main by overproduction through the application of the flotation process to complex ores. Although the surplus previous to the present trade depression was beginning to be absorbed, partly through new industrial uses for the metal, there is a very large reserve of zinc ores, and only moderate prices can be expected.

Estimated vs. actual metal prices.—It is interesting to compare ten-year forecasts of metal prices with the actual prices revealed for the periods. In 1910 and in 1920 two distinguished mining engineers essayed to predict average prices for the more important metals for the succeeding ten years. These figures were put forward to assist young engineers in placing a price on metal product for the purpose of valuing mines. These estimates were as follows:

	Cents Per Ounce,	Cents per Pound			
	Silver	Copper	Lead	Tin	Zinc
Engineer X					
for 1911–1920:					
Estimated production price	44	11.5	3.5	22	4
Estimated average price	52	14	4.3	29	5
Actual average price	73	19	5.9	51	8
Engineer Y					
for 1921–1930:					
Estimated production price	48	13	4	25	5
Estimated average price	60	15	5	38	6
Actual average price	60	14	7	47	6

The estimated average prices for 1911–1920 were greatly upset, as would naturally be expected, by the boom market caused by the World War; but the estimates for 1921–1930 by Engineer Y are close enough to the actual prices to indicate that competent judgment may reduce to a reasonable extent the risk of valuing a metal mine on the basis of "sensed" future prices. The figures also empha-

size the need for expressing the value of the mine at two price levels, a maximum and a minimum.

Records of past average prices.—Table 9 shows average prices, average high prices, and average low prices for periods of five years or more in the past. Such averages, although future prices cannot be deduced from them with any certainty, are of value in showing the upper and lower limits to which prices have swung in past years.

TABLE 9

METAL PRICES

	Silver, Cents Per Ounce	Copper, Cents Per Pound	Lead, Cents Per Pound	Tin, Cents Per Pound	Zinc, Cents Per Pound
1896–1905					
Average	59.32	13.16	3.95	22.13	4.58
Average high	67.06	16.67	4.47	29.90	5.75
Average low	52.16	10.76	2.98	13.29	3.63
1906–1915					
Average	60.06	14.14	5.07	36.96	5.74
Average high	66.79	20.00	5.66	46.10	6.94
Average low	51.50	12.38	3.06	29.73	4.76
1896–1915					
Average	59.69	13.65	4.51	29.55	5.16
Average high	67.06	20.00	5.66	46.10	6.94
Average low	51.50	10.76	2.98	13.29	3.63
1916–1920					
Average	80.93	23.00	6.70	61.20	10.09
Average high	111.12	27.20	8.79	100.00	13.23
Average low	49.68	17.28	4.67	38.59	7.34
1921–1930					
Average	59.87	13.98	6.85	47.01	6.16
Average high	63.96	15.63	7.55	52.41	6.96
Average low	56.19	12.81	6.27	42.30	5.53

INFLUENCE OF PRICE IN THE VALUATION OF A BASE-METAL MINE

In Examples 1 to 8 the present value of a mine producing one metal of unvarying price—that is, a gold mine—was determined, and a financial plan for its purchase and development was outlined, based on the present value of its annual dividend for nine years. The student must not be left under the misapprehension that there is no more to be known about estimating the value of mines, or that there lurks no danger in using the same procedure when valuing a

mine producing metals that vary in price from day to day. It is proposed to work out in the following Example 9 the present value of a hypothetical mine producing three metals—lead, zinc, and silver—and to point out the influence that variation in the price of any one of the three will have upon the financial plan for its operation.

EXAMPLE 9

Assume that the ore in the mine has been sampled and assayed, and that the proved and probable ore blocks have been mapped and calculated. From this data it may be said there appears to be reasonable geologic certainty that the ore reserves are 3,650,000 tons of the following adjusted assay: lead, 18 per cent; zinc, 18 per cent; and silver, 18 ounces.

The proposed metallurgical plant, it has been decided, will have a capacity of 1,000 tons a day, or 365,000 tons a year, thus giving a life for the mine of 10 years.

Laboratory and mill tests and trials, it is assumed, show that the following recoveries can be expected:

Lead: 85 per cent recovery in the form of a lead concentrate assaying 60 per cent lead, 3 per cent zinc, and 50 ounces of silver.

Zinc: 85 per cent recovery in the form of a zinc concentrate assaying 50 per cent zinc, 5 per cent lead, and 12 ounces of silver.

Finally, assume that these two products can be sold to smelters situated at some distance from the mine on terms defined in contracts running for 10 years.

With these assumptions it is now possible to determine the number of tons of these two concentrates that will be produced. It will then be easy to assume a range of prices for the metals and calculate the annual dividend and present value of the mine for various market prices within that range.

In an ore assaying 18 per cent lead there are 360 pounds of lead per ton; at the assumed 85 per cent recovery, this yields 306 pounds of metal recovered per ton of ore treated. This amount, it has been assumed, will be in the form of a 60 per cent lead concentrate; therefore $(306 \times 100) \div 60 = \mathit{510}$ pounds of 60 per cent lead concentrate will be recovered from the treatment of each ton of original ore. This concentrate will assay, it is known, 3 per cent zinc; therefore there will be $(510 \times 3) \div 100 = \mathit{15.3}$ pounds of zinc in the lead concentrate. The concentrate, it has also been assumed, will assay 50 ounces of silver per ton; therefore it will contain $(510 \div 2{,}000) \times 50 = \mathit{12.75}$ ounces of silver. The concentration

ratio of ore to lead concentrate will be 2,000 ÷ 510; i.e., *3.92* tons of ore yield one ton of lead concentrate of the assumed assay.

In an ore assaying 18 per cent zinc there are 360 pounds of zinc per ton; at the assumed 85 per cent recovery, this yields 306 pounds of metal recovered per ton of ore treated. This amount, it has been assumed, will be in the form of a 50 per cent zinc concentrate; therefore (306 × 100) ÷ 50 = *612* pounds of 50 per cent zinc concentrate will be recovered from the treatment of each ton of ore. This concentrate will assay 5 per cent lead; therefore there will be (612 × 5) ÷ 100 = *30.6* pounds of lead in the zinc concentrate. The concentrate, it has also been assumed, will assay 12 ounces of silver per ton; therefore it will contain (612 ÷ 2,000) × 12 = *3.67* ounces of silver. The concentration ratio of ore to zinc concentrate will be 2,000 ÷ 612; i.e., *3.27* tons of ore yield one ton of zinc concentrate of the assumed assay.

These calculations may be arranged in tabular form and checked to reveal any inconsistency:

TABLE 10

CONTENTS OF LEAD AND ZINC CONCENTRATES

	Assay			Contents		
	Lead, Percentage	Zinc, Percentage	Silver, Ounces	Lead, Pounds	Zinc, Pounds	Silver, Ounces
510 pounds lead concentrate....	60	3	50	306	15.3	12.75
612 pounds zinc concentrate....	5	50	12	30.6	306	3.67
Total metals recovered in two concentrates				336.6	321.3	16.42

It is evident that 336.6 ÷ 360 = *93.5* per cent of the total lead in the ore is accounted for in the two concentrates; 321.5 ÷ 360 = *89.3* per cent of the total zinc is accounted for; and 16.42 ÷ 18 = *91.2* per cent of the total silver is likewise accounted for. These amounts seem reasonable and consistent.

On the assumption that 1,000 tons of ore assaying 18 per cent lead, 18 per cent zinc, and 18 ounces of silver will be treated each day, the following two salable products will be daily produced:

1. 510,000 pounds or 255 tons of lead concentrate assaying 60 per cent lead, 3 per cent zinc, and 50 ounces silver.

2. 612,000 pounds or 306 tons of zinc concentrate assaying 50 per cent zinc, 5 per cent lead, and 12 ounces silver.

Now, assume that the 255 tons of lead concentrate can be sold

to a lead smelter under a contract and schedule that can be reduced to the following arithmetical expression:

Payment per ton of concentrate at the mine bins =

$$(90\%\ \text{Pb})\ (\text{P} - 1.65\ \text{cents})\ (2{,}000) + (\text{Ag})\ (\text{P}' - 3.5\ \text{cents}) - \text{T}$$

where

Pb = per cent assay of lead
P = price of lead per pound
Ag = ounces of silver per ton
P′ = price of silver per ounce
T = treatment and freight charges made up of various items as specified in the contract

It is assumed that the zinc content of the lead concentrate is too small to bring either penalty or payment. Under this schedule, T is stated to be \$38.90 per ton. The only remaining unknown quantities in the arithmetical expression are P and P′, the prices of lead and silver. For the present, these will be taken to be 5 cents a pound for lead and 50 cents an ounce for silver. The calculation of payment for the lead concentrate then becomes:

$$(.90)\ (.60)\ (5 - 1.65\ \text{cents})\ (2{,}000) + 50\ (50 - 3.5\ \text{cents}) - \$38.90 = \textit{\$20.53}\ \text{per ton of concentrate}$$

The day's revenue from the lead concentrate will be \$20.53 × 255 = \$5,235.15 from 1,000 tons of ore, or \$5.24 per ton of original ore treated.

Assume that the 306 tons of zinc concentrate can be sold to a zinc smelter under a contract and schedule that can be reduced to the following arithmetical expression:

Payment per ton of concentrate at the mine bins =

$$(83\%\ \text{Zn})\ (\text{P})\ (2{,}000) + (70\%\ \text{Ag})\ (\text{P}') - \text{T}$$

where

Zn = per cent assay of zinc
P = price of zinc per pound
Ag = ounces of silver per ton
P′ = price of silver per ounce
T = treatment and freight charges made up of various items as specified in the contract

It is assumed that the lead content of the zinc concentrate is too small to bring either penalty or payment. Under this schedule, T is stated

to be $51.50 per ton. The values for P and P′ for the present will be taken to be 6 cents a pound for zinc and 50 cents an ounce for silver. The calculation of payment for the zinc concentrate then becomes:

$$(.83)\ (.50)\ (6\,\text{cents})\ (2{,}000) + .70\ (12)\ (50\,\text{cents}) - \$51.50 = \textit{\$2.50} \text{ per ton of concentrate}$$

The day's revenue from the zinc concentrate will be $2.50 × 306 = *$765.00* from 1,000 tons of ore, or $0.765 per ton of ore treated.

The total daily income can then be stated as follows:

Income from 255 tons of lead concentrate	$5,235.15
Income from 306 tons of zinc concentrate	765.00
Total	$6,000.15 ±

This is the income from 1,000 tons of ore, and is a net recoverable value of $6.00 per ton at the following metal prices: lead, 5 cents a pound; zinc, 6 cents a pound; silver, 50 cents an ounce.

If operating cost is assumed to be $4 a ton, the net profit per ton available for dividends may be set forth as in Example 8:

Net recoverable value	$6.00
Deduct operating cost	4.00
Operating profit	$2.00
Deduct 20 per cent for city office expense	.40
Net profit per ton available for dividends	$1.60 ±

At this profit per ton on a yearly production of 365,000 tons, the profit available for dividends will be $584,000 a year for the ten years of the mine's life.

If it is desired to obtain interest of 20 per cent on the mining investment and the return of capital in ten years, the present value of the mine, computed by the use of the nomograph (Fig. 5), will be $584,000 × 3.52 = *$2,055,680* ±. This present value is based on selling prices for the metals of 5 cents a pound for lead, 6 cents a pound for zinc, and 50 cents an ounce for silver.

These prices are the maximum that might be taken into consideration after an inspection of the market trends for the past hundred years. From this sum of, say, $2,055,000 must be deducted the purchase price of the mine and the capital required for installing an appropriate equipment. The cost of equipment for a 1,000-ton

daily capacity would certainly be close to $1,000,000, leaving only $1,055,000 which could justifiably be paid for the mine under the circumstances.

If the investor was content with the return of his capital in ten years and an interest rate of 10 per cent during that period, the present value would be $584,000 × 5.45 = *$3,182,800* ±. Such a low return on a mining investment, however, is not recommended.

If the present value of this mine is calculated on the basis of a lower range of prices for the three metals produced, the influence of a drop in selling price can be demonstrated.

Assume that the market price is 4 cents a pound for lead, 4 cents a pound for zinc, and 40 cents an ounce for silver. Then the 255 tons of lead concentrate, according to the smelter figures, will bring a revenue of 255 × 4.73 = *$1,206.15* per day; the zinc concentrate will not be paid for; and the net recoverable value per ton will be *$1.21*. If operating cost is $4 a ton, the mine must shut down long before the market prices of the metals have dropped to these low levels.

Calculations of present value for a varying scale of metal prices may easily be expanded to include a number of typical levels, but enough examples have been given to emphasize the peril of optimism in assuming high market prices in the valuation of a base-metal mine.

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Chapter 11

Reports on Valuation

The report by the engineer giving the results and conclusions of his valuation constitutes the sole issue of all his efforts, and these will not serve their full purpose if the results are not placed in the hands of his client in the form best suited to meet that client's needs. The report must contain the fundamental facts and the engineering conclusions drawn therefrom.

CIRCUMSTANCES CONTROLLING FORM OF REPORT

The form of report will depend greatly upon the character of the client for whom it is made. One client will desire merely a categorical answer to the question: "Shall I put half a million dollars into this property?" Another report may be demanded by the board of directors of a large company; this should contain full data upon which conclusions are based, and should be capable of meeting close criticism from a consulting engineer.

The conditions under which a report is made may also have some influence upon its form. Suppose, for example, that the property to be valued is undeveloped and the time allowed for examination is extremely brief. It is often possible, even in such a case, to render a report that will meet the needs of the client, particularly if it is obvious that the property is either utterly worthless or else an unusual bargain. Charles Catlett cites an episode of the latter sort. He was called upon to decide whether or not to recommend the purchase of 50,000 acres of coal land, and to make this decision within ten days.

Of course it was impossible to make a satisfactory investigation within that time; but the instructions were "to make the most complete examination and the most positive recommendation possible." Such instructions are often given, for no matter how much time an investor may have, he is likely to put off his decision until the last moment, and then discover that he needs more light and advice. It does not follow that engineers, after explanation and mutual understanding of the situation, should decline to undertake examination thus limited. In the case just mentioned, while only the broadest view

was possible, half the time available was sufficient to show that the property was a good purchase. The timber alone was subsequently resold for more than the entire purchase price of the land. In other words, it was easy to determine the advisability of the bargain offered, though impossible to fix definitely, in so limited a period, the value of the tract.[1]

The engineer may also come to a definite and correct conclusion, even though time be short, if the prospective purchase can easily be demonstrated to manifest some flagrant limitation—such as impossible climate, unstable conditions of government, dubious title, or insufficiency of ore—that would preclude further investigation. In such a case, any lengthy discussion of costs and geology, for example, would be useless.

It may be remarked that when time is extremely limited former reports on the same property by other engineers may be used. Objections to the use of such reports, on the ground that independent opinion is wanted, are unwarranted; old reports should be procured whenever possible, as valuable information is often thus disclosed. If the engineer is qualified to judge the facts that he encounters in an examination of a property, he is likewise competent to judge the interpretation of these facts by other engineers.

An unfavorable verdict is disappointing to the promoters of the enterprise; but if the engineer's work has been conscientiously performed, he will have the satisfaction of knowing that he has protected his client from embarking on a disastrous venture, and that no one coming after him will prove that his judgment was faulty.

The statement that the proposal can neither be recommended nor condemned should be avoided. If no decision can be reached by the engineer, he should state his reasons for that verdict and, if necessary, request more time, assistance, or information. He may, however, state the particular factors according to which, by use of the engineering method, the success of the project will stand or fall; for example, a mine may be profitable only if a certain minimal price will be paid for the metal. He might also give an opinion as conditional upon an improvement in governmental or labor conditions, lowering of the asking price, or the like.

If the mine examined is well developed and in operation, and the valuation made with all the precautions detailed in previous chapters indicates to the engineer that the property is worth the price asked, then a full report is called for. This report not only should

[1] Catlett, Charles, "The Professional Examination of Undeveloped Mining Properties," *Trans. A. I. Min. E.*, Vol. 39 (1908), p. 775.

state the facts obtained and how they were obtained but also should contain the engineer's interpretations of these facts and recommendations for their use.

All the factors of valuation listed on pages 37–39 will have more or less influence upon the judgment of the engineer that is expressed in his report. The location of the mine, for example, may have considerable moment. It may be so situated that a large operating company in the same vicinity would in all likelihood seek to add it to their properties at a substantial profit to the engineer's clients. If the engineer happens to be retained by a large operating company, he might recommend the acquisition of a neighboring mine, the ore from which could be treated at a low cost by existing plants. If a client represents a large interest desirous of obtaining a foothold in a certain district, the engineer might be justified in recommending a mine having possibilities that, though none too good on the present showing, might warrant asking a long-term option for development. At any rate, before making his report, the examining engineer should check over the list of factors mentioned and make sure that no important point has been neglected, and that no prohibitive factor—such as adverse legal, political, climatic, or labor conditions—will bar profitable operation.

The recommendations made by the engineer in his report, then, will require cool and calculated judgment which can only come from a logical analysis that is founded on straight thinking backed by professional experience.

QUALITIES OF A GOOD ENGINEERING REPORT

Before considering the separate topics that should be covered by a report on the valuation of a mine, it would be well to call to mind the qualities that every good report by an engineer should have.

Briefly, what is a good engineering report? Almost everyone will agree that it should judiciously convey to the reader, in clear and concise terms, all the facts and conclusions which, to the best knowledge of the writer, will enable the reader to act wisely in a given situation. In other words, a good engineering report will be clear, correct, concise, complete, convincing, and considered.

Clearness.—Clear writing is attained only through clear thinking. The problem confronting the engineer must therefore be analyzed, i.e., reduced to its component parts; and these parts, in so far as they can be solved, should be solved one at a time; the product of

all the factors should then be restated as a single proposition, such as, in a valuation report: "This mine is a good investment at the price asked"; "The value of this mine is estimated at two million dollars"; "This mine should give a profit if the stated recommendations are carried out."

If the report is to be clear to the reader it should be worded in a style that can be easily comprehended without special effort. As most mining reports are intended for the layman, the language should be as non-technical as possible. The statements should, moreover, be so clear that the meaning is unmistakable. The reader should not be forced to wade through a mass of bristling terminology or to puzzle out the trend of an ambiguous phrase. He wants a plain answer to a plain question, backed up by as much detail and confirmation as may be needed to convince him that the conclusions are justified.

The data given in a report will be more readily grasped if they are made easily accessible. Captions, headings, tables, maps, photographs, and other ready aids to comprehension should be used generously. Any report more than three or four pages in length should have a table of contents, or an index, or both.

Correctness.—One assumes that the engineer will present facts and figures that are as accurate as he can make them. He should also feel the responsibility of expressing these facts according to the best English usage. It is mere mannerliness to address the reader in neat and grammatical style.

The facts offered in the report should be given in sufficient detail to permit another person to check these facts were he to go over the ground independently.

Conciseness.—All material, however interesting, that does not pertain directly to the point at hand should be pruned away. The briefest statement is the best. Wordiness and circumlocution cloud the issue. A common failure in this quality of conciseness is shown by the verbose type of engineer whose ambition it is to educate his clients in geology, mining method, or metallurgy. Prolixity is also a favorite device of those who feel a deficiency in grappling with their subject, a shortcoming which they attempt to conceal in a smoke-screen of big, meaningless words.

A concise report must be coherent; that is, the reasoning should be methodical and the structure should be framed in logical order. The parts should be in proper proportion to the whole; everything

should be in its proper place. Generous use of connective words and phrases will aid the reader to perceive relationships quickly.

Completeness.—Conciseness cannot be attained by leaving out important links in the chain of reasoning; for then the reader is forced to take time to fill in the gaps himself. All information that the engineer expects will be needed should be found in the report. If any material is extensive and unwieldy, the place for it is in an appendix, and reference can be made to it in the text.

Convincing tone.—Many engineers write best when, after reaching a decision, they suppose that they are attempting in their report to persuade another to act upon their judgments. When doing this they naturally marshal their arguments in a logical array; the clarity of their points gives them confidence, and their own assurance is reflected in their writing, strengthening it with an air of conviction.

Considered judgment.—It is not the business of the engineer to give rein to enthusiasm or prejudice when writing a report. He is a professional observer and critic, not a press-agent. His judgment should be expressed in a tempered, considered, and impartial statement of facts and his interpretation of them. If he gives way to a groundless fervor of hope or denunciation he will lose the confidence of any client; and his writing may be termed a report only in the sense that it is "an explosive noise."

It goes without saying that the probable consequences of any report he may make must have no effect upon the engineer's statements to his employer. Most experienced engineers have tales to tell concerning what might be termed the psychological background of mine valuation. Among the interesting reminiscences of E. T. McCarthy[2] is an account of the suicide of a man who had been his host during the examination of a mine, the disappointing outcome of which had meant ruin to him. During his enjoyable stay the engineer had received no indication that his host was interested in the sale of the mining concession. Another incident shows how personal abuse and baseless attacks may be the portion of the engineer who, honestly and fearlessly, renders a report that is distasteful to local opinion.

THE WRITING PROCESS

Suppose that a person has been assigned to write his views upon a given subject. It is almost impossible for him to sit down and

[2] *Incidents in the Life of a Mining Engineer; Further Incidents in the Life of a Mining Engineer.*

immediately dash off, from beginning to end, a finished composition; yet this is what the tyro frequently attempts to do when he takes pen in hand and awaits the coming of "inspiration." A brief note upon the writing process, and the thinking process that must precede and follow it, will not be out of place in a chapter on mine reports.

A comparative study in the field of the psychology of creation and invention would probably show that the processes through which the mind must pass in solving any problem are fundamentally the same, no matter whether the problem be one of inventing a machine, a technical treatment, a design, a plan of organization, or a mathematical technique;[8] even artistic creations such as a musical composition, a painting, or any type of written work are subject to similar stages of invention before a finished result is produced. The expression of this result in a form suited for its communication to others is merely a portion of the creator's task; in other words, the physical act of writing a statement of an idea on paper is only one stage in the conception and expression of an idea, and must be preceded and followed by a series of mental acts, both conscious and non-conscious.

This process may be divided into seven periods of activity, each of which may in a particular instance require little or much time. The first stage is the *conception* of the need for a solution to a problem which has arisen from previous study or from a pressing situation. Suppose that the problem can be solved, at least in part, and that this solution is to be reduced to writing. Then, if the solution is to be successfully conceived and expressed, six other interrelated stages must follow. The first of these is a period of *preparation,* which includes the focusing of all past experience on the problem; this may need to be supplemented by special organized study and research. Then follows a period of *incubation,* which may require several years or only a few minutes, during which time the mind plays freely over and about all possible solutions, rejecting those that are impossible or that do not agree with the individual's conceptions of rightness or good taste. Exceptional ability, practice, or so-called "genius" may shorten this stage by quickly eliminating all false leads, or by jumping intuitively, or by means of extremely rapid and scarcely conscious reasoning, to a conclusion. This conclusion may not come clearly at first, but may appear merely as an

[8] See Baker, R. P., *Engineering Education,* essay by Henri Poincaré on "Mathematical Creation," pp. 126–38.

intimation, a sort of "fringe reaction," when one feels that a proper solution has barely escaped one without being able to seize upon it, even as a mote slides out of sight before the eye is able to fix upon it. The stage of *illumination* may finally come in a flash, when the mind is ostensibly engaged in thinking of something entirely different, or it may dawn slowly and grow by means of laborious concentration. Notes of sufficient length to retain the memory of these flashes of thought should be made if there is any danger that they may be lost. Now, and not until now, is it possible to give *expression* to the idea, by putting the whole argument on paper in logical and exact form. In order to do this, it is almost always necessary to make first a structural outline which may guide in orienting the parts to the whole; although practice may aid an individual to dispense with an actual written outline, he must in almost every case have in mind a definite mental outline to follow if the composition is to appear as an ordered and coherent whole. The necessity for concentrated reasoning and accurate statement during the period of expression often leads to the formation of new ideas or an expansion of the original, or to working out a happier turn of phrase, so that even this period is less one of a merely physical task than one of extended thinking. Since it is usually impossible to concentrate simultaneously on the manner of expression as well as the matter to be expressed, some authors favor writing off a first draft of an idea at a white heat, leaving revision until a later time. However, owing to the fact that, once an idea has been clothed in words and written down, it attains an air of immutability which makes it hard for the mind to conceive of other possible ways of expressing it, some writers favor the attempt to put the first draft in as excellent a garment of expression as possible—revision is always a laborious task. Revision is always necessary, none the less, and this final stage of *revision and verification* entails a period of analysis, criticism, elaboration, pruning, substitution, and polishing, until the composition appears best suited to the fulfillment of the author's intention and to the needs of the reader.

The period of incubation, it has often been noted, is frequently carried on subconsciously; that is, after the problem has been posed and the necessary preparatory study made, the problem may be submitted to the so-called subconscious mind, which carries on much of the laborious work of manipulating and combining and shuffling and eliminating possible combinations, until a valid—or at least a satisfying—conclusion pops into the conscious mind. However, since the subconscious mind apparently cannot manipulate factors which

have not been previously stored in the memory and cannot deal in any ideas beyond the experience of the conscious mind, it cannot present a solution beyond the mental scope of the individual. For this reason, the preparatory work *must be done;* although a period of concentration on a problem may appear fruitless at the time, this initial spade-work has had the effect of storing the subconscious with the materials from which may be drawn a solution, and of setting the subconscious selective process to work. Since this process cannot be depended upon to present, as a matter of course, a valid solution, the work of verification and revision by the conscious, reasoning will must also be undertaken in order to curb the expression of an obviously fallacious argument.

It may thus be seen that the process of writing is much more than the act of putting words on paper. This act, although highly important, is a mere crystallization and recording of a number of mental acts which must precede the choice of words and the selection of a mode of communication. The novice is directed, for details of rhetoric and style, to suitable textbooks, a few of which are listed in the bibliography.

SUGGESTED FORM OF VALUATION REPORT

The first notification to the client that the engineer has reached a decision will probably be a telegram, perhaps in code; the message may vary from "Property absolutely worthless," "Property has some merit, but advise you to drop it," to "Property highly valuable; make every effort to secure it." This telegraphic report may also give a condensed statement of the basis on which valuation was made.

The extended report will follow by mail. This report may be accompanied by a letter of transmittal, which may repeat in brief form the purpose of the report, conclusions, amount of time and money spent in the examination, and the recommendations.

The following outline is suggested as a logical form for a valuation report. It should, of course, be altered to suit the needs of the individual situation.

1. Title page
2. Table of contents
3. Purpose of report
4. Conclusions
5. Situation of property; distances, transportation
6. General and limiting conditions
7. Description of property

8. Legal title to property
9. History of property and district; past production, costs, and profits
10. Geology of deposit and district
11. Development
12. Samples
13. Ore reserves
14. Treatment methods
15. Equipment
16. Costs
17. Metal prices
18. Existing contracts and regulations
19. Financial requirements; estimation of profit
20. Date of examination; time and money expended
21. Recommendations
22. Summary
23. Appendixes
24. Index

Title page.—The first page of the report should give at least the name and location of the mine, the name of the engineer, and the date of examination, as:

Report on the

BIG BONANZA MINE
Sulphuret, Nevada

by

E. E. Pehrson
1932

Table of contents.—The table of contents should occupy not more than one page, and should include some selected list of topics such as the 24 points above enumerated, giving the pages on which each appears.

Purpose of the report.—To understand a report it is necessary to know under what instructions and conditions it was made. The report may be made to aid the client in determining whether or not the property should be purchased for a stated sum or a long—and possibly expensive—working option acquired; or the question to answer may simply be: "Is it worth while to make a thorough examination?" In another case, the engineer may be sent on a scouting expedition to see if it be advisable to establish a foothold in a growing camp through the acquisition of options on promising properties. Other questions might be: "Should further capital be raised to carry on a mine now in operation?" "Should an expedition

be arranged to study a concession covering a large area?" "Should a certain property be abandoned?" or "Should two properties combine for the purpose of economizing in treatment costs?" These are but a few of the conditions under which a report may be made, and it is quite necessary that the report, or the covering letter, state clearly just what condition the engineer has been asked to study.

Conclusions.—The conclusions reached by the engineer are the most important part of the report, and should be set forth as early as possible. The results of the examination are, in the client's estimation, the conclusions and recommendations; he may need to know nothing more. And all other readers of the report—engineers, investors, or mining reporters—will get at the meat of the matter the sooner for knowing the conclusions at the start.

Conclusions should be put in a few clear, crisp words; too much pains cannot be taken to make them an epitome of the whole result of the investigation. The conclusions, although standing at the head of the report, are, of course, written last.

While every effort should be made to present a plain and unambiguous conclusion, yet there are many mines which are attractive as investments provided a different course can be followed than that outlined when the examination was undertaken. In such case it is quite proper to discuss various alternatives and indicate what might be done to make the investment of funds more profitable.

Situation of property.—A few short sentences are usually enough to give the geographical location of the property. Latitude, longitude, and altitude should always be given, with some description of topography and climate. If the property is in a well-known region, nothing more is necessary than a small map showing railway connections and routes to the mine; but if it is remote—in countries such as Peru, China, Siberia, or Alaska—an itinerary may be inserted in an appendix showing times and distances of alternative routes to the property.

General and limiting conditions.—Any general factors which may be unknown to the client, and which may limit or prevent operations, or affect production or costs, should be here noted. Such factors might include climatic, governmental, and labor conditions; topography; transportation problem; and availability of water, supplies, and power.

Description of property.—As complete a series of maps as possible should accompany the report. These should include a map of the

surface, showing topography of the district, location of mine openings, buildings, and boundaries of claims. District maps indicating the position of adjoining mines, roads, and watercourses will be useful. If the mine is in operation these plans, as well as those of underground workings, will be easily obtained; seldom will it be necessary for an examining engineer to devote much time to making accurate maps, for nowadays it is rare to find a mine without an underground plan. If, however, accurate maps are not to be had, a plane-table survey of the surface and a transit survey of the underground workings will usually suffice to make the written description plain. The amount of detail to be shown on the maps will depend on the extent of the development of the property. Sketches and photographs of the surface will generally be sufficient.

It is well for the engineer to be sure that all plans furnished him are correct, and the precaution, mentioned earlier, of having the mine officials sign a guaranty of the correctness of such maps, should be taken.

Legal title to property.—An engineer is usually incompetent to pass on the validity of legal titles to properties, and he should insist on explicit, written instructions concerning the steps he should take to investigate such titles. These instructions will presumably be given to him by the client's lawyer, who will probably be able to designate some attorney in the district to assist in the investigation of legal aspects.

With the aid of this local lawyer, and with such other information as he can gain, the engineer must examine such difficult problems as that of extra-lateral rights—in the past one of the chief drawbacks to mining in the United States—and report fully what he learns. It is, nevertheless, not the duty of the engineer to take any firm stand with regard to the liability of lawsuits over title complications and mining rights, for such questions must be left for the decision of the client and his legal adviser. The engineer's function is completed when he has reported what he has found out.

If the engineer has been employed by clients who are inexperienced in the business of mining, he should recommend that a guaranteed title be obtained before any payments are made on the purchase of the property.

History of property and district.—Salient points in the history of the property and of other mines in the district should be noted. These may include past records of production, costs, profits, tailings values,

and any other helpful data. For deep mines, data on comparative values at various depths are desirable.

Properties of any considerable age are sure to have passed through many vicissitudes, all of them interesting to a prospective purchaser. The engineer cannot always verify all the history of a mine, and tales of high production and rich ore should not be accepted without good evidence. Legends grow rapidly on mining soil and never lessen in retelling. Information advanced by "boosters" —those people who as local property owners have a stake in the prosperity of their town—is to be looked upon with suspicion. Most of the populace are boosters; but even the word of the booster's enemy, the "knocker," is not altogether to be trusted, for he may be a man with a grudge.

Abandoned metallurgical plants are warning signs and should impel the engineer to seek the causes of failure, so that they can be avoided. Such abandoned plants may indicate that the ore is too refractory to be profitable.

Geology of deposit and district.—The statement of geologic conditions is often made an occasion for a quantity of fancy and utterly meaningless writing. The language used in describing the deposit and the surrounding district should be simple and brief, and the points covered, while depending upon the particular nature of the formation, will generally not exceed the following: (1) extent of ore zone; (2) form of deposit; (3) structure; (4) classification according to type of deposit; (5) nature and weight of ore and mineral contents; (6) enclosing rocks; (7) strike and dip; (8) number, size, and shape of ore shoots; and (9) faults.

Many words may be saved by reducing geologic description to maps. Drawings of longitudinal and horizontal sections, longitudinal cross-sections, and other sketches will tell in a few pages what a volume of verbal description could not tell in half so clear a manner. Maps, tables, charts, etc., should be liberally captioned so that they are self-explanatory even when considered apart from the text.

There is little value in attempting to name scientifically the rocks encountered in the field; local names can be used and, if corrections are strikingly needed, specimens taken on the spot may be submitted to a competent petrologist for identification and the proper names then inserted in the report.

As a matter of experience, it is extremely seldom that an expert knowledge of the whole science of geology is decisive in the accurate

valuation of a mine. The chief use of geology in mining is for the direction of exploratory work; it is of the greatest value in estimating the continuations of faulted veins, possible extensions with depth, and probable changes in tenor of ore.

Development.—The various shafts, drives, and winzes that have been made to open the mine for development and inspection are best shown by maps. If these maps are complete, including general plans, cross-sections, projections on the plane of the deposit, and plans of separate levels, there is little need for much explanatory matter, but enough should be given to make the meaning of the maps quite clear. A general plan of a mine that is working on a vein of steep dip, where the levels overlap each other in the horizontal plane, is confusing to the ordinary engineer and almost unintelligible to the layman. For the understanding of the openings in a mine of this sort, separate level plans—preferably on the same sheet—are urgently needed.

Samples.—The tabulations giving sampling results should be preceded by a short statement of the persons who took the samples and the method used. The tabulations should set forth in detail the assay returns from sampling for each block defined by the various levels, winzes, raises, and crosscuts. A copy of the assay plan, since it is usually unwieldy, should be inserted in an appendix. Methods of crushing, quartering, and assaying should be briefly described.

"Illogical precision," or the statement of results to a number of decimal places that is not warranted by the accuracy of the data on which results are based, should be avoided in the final statement of sampling returns. When calculating these returns, however, the widths measured and assay values found may be carried to a reasonable number of places; the figures should not be rounded off until the final results are obtained. Since the original data will be in error to some degree, one is justified in stating calculated results to the nearest round number. Such a statement as "The tonnage is 368,745.37 with an average value of $31.8746" implies that the figures are exact to a degree that is humanly impossible, and is therefore misleading. In this case, the correct statement would be "369,000 tons with an average value of $31.87."

Ore reserves.—Calculation of ore reserves should follow the principles stated in chapter 6. The mine will be divided into blocks and the tonnage and value of each block is computed and listed separately. Each block is given a letter or number, and then classified

under one of the headings of proved, probable, or prospective ore. In the body of the report, it will be sufficient to give in tabular form the estimated value of ore reserves and prospective ore, a diagram showing the various blocks included in the calculation, and a full explanation of the reasons for classifying the blocks under the various headings. The meanings of the terms "proved," "probable," and "prospective ore" should also be defined in the report.

The following will illustrate the form of tabulation used to show ore reserves and prospective ore. It will be noted that here, as when showing sampling results, illogical precision is avoided, and figures are shown in round numbers.

ORE RESERVES AND PROSPECTIVE ORE

	Tons	Value	Total Value
Ore reserves			
Proved ore	1,000	$35	$ 35,000
Probable ore	2,000	25	50,000
Total ore reserves	....	...	$ 85,000
Prospective ore	4,000	$30	$120,000

Treatment methods.—Methods of mining and of subsequent treatment of the ore as practiced at the mine should be detailed, and possible improvements suggested.

If the mine is in a region where similar deposits have been worked for a number of years, criticism of the methods employed should be governed by caution, for it may be found after longer acquaintance that the methods employed are the best suited to local conditions. But in any event, the engineer should consider very carefully the probability of adding to the value of the property by improvements in either mining, metallurgy, transportation, labor conditions, or source of supplies. Full details should be given in the report, and recommendations repeated under the proper heading.

Equipment.—The report should contain a description of the existing plant and equipment, and suggestions for possible improvements.

Costs.—The points covered in chapter 7, which deals fully with costs, should be reviewed during the actual examination. Costs must be given in the report at reasonable length, but voluminous tabulations may be relegated to an appendix and merely summarized in the text. The engineer should remember that in a valuation report the cost figures required are those that bear directly on the value of

the property to a purchaser. Any factors that might lower or raise costs in the future should be pointed out.

Metal prices.—Future prices of metal products are of prime importance in valuation. If the responsibility for predicting future prices must be assumed by the engineer, he must do the best he can; but he should clearly state, as indicated in chapter 10, that any variation from his assumed price will directly alter the valuation of the property. Preferably, he should give figures for several possible alternative prices and show what effect each would have on his valuation, and how variations in price would change the value of the property.

Existing contracts and regulations.—Any contracts or legal liabilities that will be assumed by a purchaser of the property should be studied with great care by the engineer and the legal adviser of his client. Not only will contracts for the sale of ores and concentrates have a decided effect upon profits, but there are in many countries a swarm of restrictive regulations, agreements with labor unions, and traditional business methods that may develop into expensive and vexatious drawbacks to profitable operation. Hence all existing agreements, tacit or explicit, must be examined and reported. Especial attention must be given to actual or threatened lawsuits.

Financial requirements; estimation of profit.—The results of the financial analysis recommended in chapter 8 should be stated in the report. Full consideration should be given by the engineer to the amount of capital needed and to the rate of interest that the investment should pay. More than one mine has had to discontinue operation because the valuing engineer was optimistic in his estimate of the sum that would be needed to develop and equip it to the point of actual remunerative production.

Many financiers feel that it lies outside the province of the engineer to decide whether or not the undertaking will yield a fair return to the stockholders. But some of the most honored mining engineers have felt a duty to the public as well as to their immediate employers, and have lost favor with cliques of promoters because of their criticisms of proposed financial plans for operating mines. If the valuing engineer suspects at the beginning that his report may be used to further an obviously disreputable promotion scheme, he will, of course, refuse to associate himself with the affair. Since the engineer may have to bear the brunt of criticism after a mining

failure, he should insist that if his name and report are used in its promotion his statements shall be fairly quoted. Finance, economics, and technology are today so interwoven that the engineer must employ all of them if he is to protect his name and serve the public interest.

Date of examination; time and money expended.—The dates during which the examination was made should be noted, at least on the title page of the report. It may be advisable to state in the body of the report the amount of time and money expended in the course of the examination; but this information might preferably be included in the letter of transmittal.

Recommendations.—This section of the report will usually be that of greatest value to the client. Statements in appropriate detail may be made concerning possible improvements and savings, accompanied by criticisms of existing methods.

Summary.—This section should epitomize the data in the report and the conclusions drawn from the facts given in the previous sections, and will repeat to some extent the brief conclusions placed at the head of the report. It will show how these conclusions were reached by reasoning from the given facts, and will explain the logic that prompted the decision expressed.

Appendixes.—The appendixes, numbered for reference, will, as has been intimated, be used as a catchall for data too bulky or extensive or distracting to be included in the text. The gist of the information may be given in the body of the report, and the reader referred there to tables, cost sheets, assay plans, and other valuable but voluminous data included at the end of the report. Such material should always be labeled by captions that will make it self-explanatory.

Index.—A well-compiled index will be of inestimable value to any reader wishing to refer to a paragraph or statement concerning a particular phase of the study.

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Part Two

MINE ORGANIZATION

Chapter 12

The Origins of Co-operative Effort

A social order based solely on the efforts of individuals who are all directly competing with each other would produce few noteworthy achievements in engineering. Such an order would be able to perform no greater feats than those of Crusoe on his island. Engineering enterprises, and especially mining, require co-operative effort. This co-operation is attained by the unification of various individuals into a group having a common purpose. Some individuals of the group contribute money, others contribute money and time, still others time, effort, and brain-power. The process of combining these parts and systematically directing the organic whole thus formed toward a common aim is what is meant in these pages by "organization."

THEORY OF ORGANIZATION

In chapter 1 organization was listed early among the steps in an engineering project and "management" was said to be a function applicable at all points in the development of the project. It is not easy to distinguish between organization and management unless one agrees to consider organization as the initial scheme of co-operation which defines the structure and function of the business unit, and management as the application of organized effort to carry out the policies of the administration. The theory of mine management will be developed at length in Part Three.

The problems of mine organization covered in the present section will deal with the following topics: early forms of co-operative effort in mining; types of modern business units, their structures and functions; the promotion of mining enterprises; stock exchanges and the mining investor; booms and panics; protection of investors; the valuation of shares; frauds and fallacies; financial policy; and mining law. All of these topics are more or less intimately related to the application of organized effort to the business of mining.

The conception stated above is that of organization in a capi-

talistic country. All those individuals who join an organization expect some sort of reward and our constitution and laws, among other functions they perform, provide for the distribution of the rewards for this combined organized effort. We believe this system is the best yet devised for the purpose of achievements designed to increase the modicum of individual comfort, although there are no doubt some inequalities to be corrected, and we believe that other systems fail because they do not provide an equitable and adequate reward.

EARLY FORMS OF ORGANIZED EFFORT

The desire to obtain the minerals of the earth led mankind to work together for this purpose early in the life of the race; and even under the oldest civilizations, when historic events were recorded on stone, some sort of systematic organization was already in existence for the purpose of discovering and exploiting mineral deposits. From the time of the First Dynasty in Egypt to the present a number of diverse types of organized mining enterprise have grown up. It will be interesting to glance at the most important of these to see how they are related to the business units in existence today. We note an increasing complexity of organization with the increasing demands of modern society.

Egypt.—The form of organization for mining purposes existing in ancient Egypt may be taken as typical of group effort with monarchic control. As early as the reign of Semerkhet, in 5200 B.C., expeditions were regularly sent out by the king to obtain copper and turquoise from the rocky country about Mount Sinai. These expeditions[1] were directed by officers of the king, and the labor was performed by slaves of many castes, each with a special duty. Under such a form, the individuals contributing to the organized effort were bound by submission to their royal overlord, for whose benefit alone the venture was undertaken. In other words, the king was the only shareholder and received all the dividends. The benefits accruing to the other human units of the enterprise were dependent upon the generosity of the king.

Ancient Greece.—Private organization for mining is known to have existed in Greece, where the rich lead-silver mining district of Mount Laurion was worked from 700 to 200 B.C. The land was

[1] See Petrie, Sir Flinders, *Researches in Sinai.*

held to be the property of the state, but the republican ideals of the people were no doubt responsible for the development of an organization under which private individuals leased the right to mine the metals. It is known that Xenophon at one time urged the citizens of Athens to form mining companies in order to improve the finances of that city, and Herodotus speaks of rich mines of gold and silver on the island of Siphnos in the Aegean, the yield from which was divided year by year among the citizens. The lessee was required to pay a large tribute to the state, and there were elaborate provisions governing the rights to mine and regulating the conduct of the work, which was performed by slaves.[2]

Roman Empire.—The Romans were intensive seekers of mineral wealth, and the theory of state ownership of mining land was first worked out by them in detail and embodied in numerous laws for the regulation of mining in various parts of the empire.

> With the conquest of the older States, the plunderers took over the mines and worked them, either by leases from the State to public companies or to individuals; or even in some cases worked them directly by the State. There was thus maintained the concept of State ownership of the minerals which, though apparently never very specifically defined, yet formed a basis of support to the contention of regalian rights in Europe later on.[3]

Rights to mine were held on terminable leases, and it is likely that operation by private companies increased with any weakening of central authority. As in Greece, most of the labor was performed by slaves.

The Middle Ages.—During the Middle Ages the feudal lords were diligent in attempting to enforce the Roman concept that the minerals in the earth were the property of the sovereign, and the right to mine was delegated to individuals or groups by charters, which set forth the privileges of the holder and the tithes to be paid to the overlord. A number of mining communities grew up during these chaotic centuries, and the first charters of which any record remains no doubt crystallized a number of traditional usages which had developed through generations. Many of these customs were elaborated, as time went on, into practical codes of mining law, and some of these usages are still to be encountered in the modern mining codes of many countries. Chief among the concepts was the old Roman doctrine of regalian right.

[2] See Agricola, Georgius, *De Re Metallica,* translated by Herbert Clark Hoover and Lou Henry Hoover, footnote, pp. 82–85.

[3] *Ibid.*

The cost-book system.—A most interesting early form of mining company, which was the type most prevalent during medieval times, is described by Agricola in Book IV of *De Re Metallica;* and in Cornwall, where it was early in use, it came to be called the "cost-book" system. Briefly, this form of organization is a system of dividing a mine into shares, which were purchased by a limited number of part-owners, usually living in the mining community. These joint owners, or "adventurers" as they were called, supplied all capital and shared all profits. The cost-book system cannot be called a partnership, because it is something more; nor can it be termed a joint-stock company, since it is something less than the modern company, of which it was the forerunner.

The mining communities of Cornwall and Devon were by the early part of the thirteenth century chartered as corporations possessing many powers of self-government but paying "coinage" to the crown on the tin they mined. Private enterprise was encouraged, and the desire to speculate led men to organize for mining purposes under the cost-book system, which in somewhat similar form could doubtless be traced back to Grecian antiquity and which in isolated cases has survived to the present day. The mine or tunnel was divided into a number of equal shares, and the owners of these shares formed the directing board. These men met frequently, at intervals of no more than a few weeks apart, and liquidated the accounts, sharing profits or paying assessments for the coming period of operation. The powers of superintendence were periodically delegated to one of their number, called the "purser" or "agent," whose duty it was to keep records of proceedings, names of shareholders, and accounts, and otherwise act as the administrative head of the company. The license or lease to dig for minerals was granted to the purser or one of his co-adventurers, never to the company as a separate entity. The purser was not usually a technical man; he hired a "mining captain" to carry on actual operations.

The company under the cost-book system was on the whole an efficient operating group. The adventurers held full power and were direct owners of the mine; they were chary of delegating their rights, and were in position to make the management of operations immediately responsive to their wishes. They were in close and frequent contact with activities at the mine, could examine the cost book and all other records at any time, and each man was at liberty to withdraw from the company on one month's notice by settling all claims against him. The chief disadvantage of the system was

that it could not exploit large mines for which a great amount of capital was needed. It was also weak in its provision for technical control; the modern conception of engineering administration was almost wholly lacking and therefore the system was inadequate for the needs of modern industry. It seems doubtful, however, if investors in corporations of the present day receive as generous profits as did many of the old cost-book adventurers, whose profits from careful operation of small, rich mines are impressive even in these days of million-dollar mining finance. For instance, in 1844 the Devon Great Consols mine was started under the cost-book system with a capital of £1,024 in shares of £1 each. No more capital was "called," and in six years the dividends amounted to £200,000; in 1853 the £1 shares stood at £430. The Tresavean mine, after reopening with a capital of £1,000, made a profit of £1,000,000. Losses under the system, however, could also be great; a Mr. Cave lost almost £200,000 by speculating in twenty-seven different mines.[4]

MODERN FORMS OF MINING ORGANIZATION

Mining is today carried on under many differing types of organization, ranging from the individual effort of the prospector working his claim unaided to the co-operative effort of immense companies having thousands of shareholders and operating in many parts of the world.

Individual effort.—The simplest type of mining business is that represented by the "one-man mine" worked by a single individual. In the past it has not been unusual to find many men devoting part of their time to prospecting for ore deposits and the remainder of their time to working as laborers to earn money with which to buy food and equipment to support them and give the means or capital to carry on the work of developing the prospect they have located. Latterly, however, the ranks of the old-time prospector—that picturesque wanderer of the desert, owning nothing but his pick, pan, and burro, yet dreaming of a new Potosí—seem to be thinning out rapidly.

The lot of the independent prospector has always been a heartbreaking and backbreaking one; and it is safe to say that not one in fifty of these men realizes anything like the financial rewards that their persistent effort would have brought them in other fields. Prospecting for metal deposits is a research activity demanding endur-

[4] *Cornwall, Its Mines and Miners.*

ance and patience and at least a rough-and-ready knowledge of geology; it is undertaken only by men of determined character; and yet for a number of reasons the independent prospector is today at a disadvantage. Among these reasons is the fact that rich discoveries are seldom stumbled upon nowadays by the uninstructed wayfarer. Moreover, large-scale prospecting has been carried on by the staffs of large exploring and operating companies, who are better equipped financially than the lone grubstaker to survey likely districts. These companies have greater financial resources, and are better able to apply scientific methods to the location of deposits.

It has been suggested that the government should maintain a staff of salaried prospectors as a division of the Bureau of Mines, but for several reasons such a proposal cannot be favored. On the other hand, the Canadian practice, by which district geologists visit prospectors and advise them on the most promising methods of developing their claims, would seem to be advantageous.

In rare cases the prospector may continue to develop his claim unaided, paying for supplies by the sale of ore he has taken out of the ground himself; but the mineral deposit would need to be extremely rich if he were to be thus able to finance himself. And it should be pointed out that, even if all the functions of the business are carried on by a single individual, the principles of organization nevertheless apply. A fanciful picture of such a one-man mine will illustrate this. It is conceivable that a man with no other equipment than that with which he was born might find himself the discoverer of a metal deposit of such richness that he could break off several pieces with his bare hands, carry them to the nearest store, and trade them for food, clothes, and a pick and shovel. The raw ore in this case would be capital, which he could convert into equipment. He might then, with the aid of his new outfit, dig out a larger amount of ore, carry it on his back to the nearest town, and with the proceeds purchase a mule, some hammers and drills and dynamite, and return again to work. The capital derived from several mule-loads of ore might be used to start a bank account, with which to purchase more equipment and hire additional labor; and so, by such steps, he might in time develop a large property. This would be a mining venture of the simplest form, but even here group association cannot be avoided. The miner must organize his staff as soon as he hires a single laborer; he must have contact with society if he is to market his product and purchase supplies manufactured by others; he must co-operate with the government to

protect his rights. The various departments of the business, although centered in this case in a single mind, will none the less be subject to the principles of organization by which the scheme of operation is structurally and functionally defined. The rugged and naked individualist is quickly transformed into a capitalist.

Such a simple form of organization is possible, but the amount of metal produced by all such one-man mines would not begin to supply the world's need, and only the highest grades of ore could be so exploited. The usual condition is that the original locator cannot perform all the functions of a mining business; he must have outside help; in other words, he must seek capital. It is at this point that group effort, which may be of the simplest kind, can add greatly to the chances of success in the venture.

Grubstakes.—It is a common practice for a prospector to seek the assistance of another person in equipping him to search for minerals or in supplying his needs while working a claim. The prospector will secure from this person—sometimes a village storekeeper—what is termed a "grubstake." This generally consists of food, tools, supplies, and a mule—an outfit sufficient for the prospector's operations for a period anywhere from three months to a year. Although such an arrangement is not properly a partnership and may have a great many variations in detail, the rights of both parties are recognized by custom and by the law. The prospector contributes his time and ability; the grubstaker contributes capital; and both are presumed to have equal title, in most cases, to any claim that the prospector may locate. In the past, grubstake contracts have commonly been oral; but in some states they are not valid unless in writing and recorded, and such recording is advisable in all cases.

The supplies which the grubstaker agrees to furnish are the consideration that makes the contract valid; and if these are not provided the prospector is under no obligation to allow the other any share in his discoveries. If, however, he is outfitted under the agreement he can be held to account for the rightful share of his grubstaker in mining claims, sale of rights, or sale of ore.

The supplies furnished must be adequate for the proposed venture or the contract will be invalid. An interesting case was decided in the courts some years ago. A man named Marks grubstaked one Swiftwater Bill by giving him $1,000 for prospecting in Alaska, on the understanding that he was to have a fifth interest in all discoveries Bill should make. The prospector found mines that were ultimately worth a million dollars, but the courts held that Marks

was not entitled to the stated share, since the agreement was unjust in that it ran indefinitely, virtually intending that Bill should work for the remainder of his life for a paltry thousand dollars. Marks should have placed a time-limit on his contract and paid the agreed amount during that time; then he would have been entitled to demand that every claim registered by Bill during the period should name him as part owner.

Some grubstake arrangements have a time-limit fixed at the period when the supplies furnished have been exhausted. This is equitable if the prospector is honest, but if he is not he may loaf and live on the fat of the land without even indulging in the mild exercise of panning a few samples. He may even feed tramps for the sake of company.

The honesty of the prospector on grubstake should extend to reporting everything he discovers and to locating claims jointly with his backer. It may be said that the average prospector, although rough and uneducated, is ordinarily capable and hard-working and transparently honest.

Another form of alliance between the prospector and his source of supply is the custom of working by the month on a salary and expenses. In such cases the prospector is usually allowed a small share in any mine he may discover.

When a mine is located by a prospector on grubstake, a new and definite arrangement should be made for the development of the property until the time when sufficient value is shown to warrant offering the prospect for sale. If the backer is wise he will not attempt to "freeze out" the prospector by demanding that he bear his part in the development expense but will attempt to continue the favorable relationship and retain the loyalty of the prospector during the exciting but frequently discouraging and expensive period of development. The chance of making a rich strike even after years of unrewarded struggle is enough to keep many seekers in the game. In one noted case after a grubstake period of eighteen years a find was made which abundantly rewarded both the prospector and his backer.[5]

Leasing.—When the prospector lacks capital, he is often glad to lease his mine for a short period. Two or three men will often take the lease and furnish everything needed for mining, and when the lease expires will hand over the equipment to the owner. The lessees

[5] Rickard, T. A., "The Romance of Mining Discovery," *Min. Sci. Press*, May 8, 1920, p. 674.

pay a royalty of 10 to 50 per cent of all the ore hoisted. The Hayes-Monnette lease on the Mohawk mine at Goldfield, which expired in January 1907, is the most profitable on record. The total product was about five million dollars, of which three million was profit. The profit to the owners was also large, and they fell heir to a developed mine with hoisting equipment and a million dollars worth of ore blocked out.[6] The owners could have made a much larger profit by working the mine themselves, but they were satisfied with the results. The presence of such extremely rich ore gave rise to "high-grading," a subject that will be treated in a later chapter.

The final phase in nearly all of the old camps in Western United States has been an era of leasing. The mines have in such cases reached a point where they are no longer profitable to operate under company management. They are then divided into sections and each section is let to a party of "tributers." The reason that these lessees can operate more effectively than a company is the elemental one that when a man is working for himself he works harder and produces more than when he is working for wages. It is no discredit to the best mine management that tributers can work more cheaply. The tributers pay a royalty of from one-sixteenth to one-quarter of the value of the ore hoisted. The company generally does the milling, making a small profit on treatment. Such leasing agreements should provide that the tributers keep the mine properly timbered.

Many profitable leases have been held on old mines. Unfortunately, some of them have been cases in which previously stolen rich ore had been stored in a mine in the hope of securing a lease. At a famous mine in California such a cache, stored away surreptitiously many years before, was ultimately found in the end of a crosscut; ten cars of this ore yielded $30,000.

The leasing or tributing method of carrying on operations not infrequently leads to another advantageous result, that of finding new orebodies. In former years mines have been rejuvenated and have entered long years of profitable history after a period of tributing. The interests of the owner should be protected by making the limit of the lease so short that while the lessee will have a fair chance of profit the owner will also share in any large discoveries.

The rules of the courts governing mining leases are based on the common law that has its origin in dim antiquity, and are so complex that they cannot be described here. Mining leases take three forms: first, a simple license to work; second, an actual leasehold of the

[6] "A Remarkable Lease," *Min. Sci. Press,* March 16, 1907, p. 344.

mine; and, third, what amounts to a sale of the mineral in place. Leasing, in the ordinary sense, generally means merely a license to work the mine.

Mining partnerships.—Two or more men may join together for the purpose of exploiting a mining claim on equal shares, thus forming a partnership. Such a mining partnership differs from a commercial partnership in that one member may retire, sell his interest to another member or to a stranger, or die, without dissolving the organization. Such a form of co-operation has a number of phases reminiscent of the old cost-book system of Cornwall; for example, a partner can on due notice withdraw from the partnership on settlement of his liabilities. The law of mining partnership is too involved to discuss here in detail, but it is worth noting that under certain conditions a mining partner may resume his standing after he has once withdrawn.

A form of partnership which more closely approaches a corporate entity is that under which the members furnish capital and hire miners to exploit a claim. Such organization suffers from certain disadvantages. The relationships of the members are unstable, though recognized by law. No large sum of money for operations can ordinarily be raised under such a system. Furthermore, in case of the death of one member his executor may demand a premature liquidation of his share, and if the remaining partners cannot buy over the share of the deceased member the venture may be wrecked. The partners are equally liable for the acts of any member, and if one partner is dishonest or unwise he may ruin the business by contracting heavy obligations in the names of his associates.

Partnership organization is more suited to the operation of mines than are individual effort or grubstaking, and many mining ventures have been carried on in the past under this form. But the mining industry requires for most of its activities even greater concerted human effort than is possible under a partnership; and this form of association, when compared with the larger organizations of greater scope and power, is seen to be limited and unstable.

Co-operative mining.—An interesting form of mining organization through some loose combination of workmen is noted by Shockley and Cranston.

Some of the coal mines of Shansi, China, opened by shafts up to 300 feet deep, are operated by combinations of workmen, where all seem on an equality. The Russian workmen also unite in a gang (*artel*) which operates

as a unit. In California the gangs of Chinese who work many alluvial and a few quartz mines seem less formally bound together than are the shareholders in an ordinary mining company. Their organization is more in the nature of a co-operative and semi-benevolent society.[7]

These mines are operated by "tongs" to furnish employment for members when better jobs are not available; and when the indebtedness of the member to the society is paid up, the worker is apparently free to share in all profits of the group.

It is understood that a number of co-operative mines exist in the United States, but little information about their form of organization is available.

The company.—The most prevalent form of modern mining organization is that of the company, which is an inclusive term covering any formal association of individuals to carry out a specified purpose such as the operation of a mine or an allied business. The type of company may range from small groups that are little more than a partnership to the huge corporations, public and private, that dominate the commerce and industry of the modern world. Company organization makes it possible for a number of scattered individuals to contribute the large amounts of capital necessary to conduct the extensive operations required to maintain modern civilization. It is desirable that the mining engineer should know the elementary facts concerning the structures and functions of the modern forms of company organization.

GROWTH OF COMPANY ORGANIZATION

Mention has been made of the fact that private companies are known to have been formed in ancient Greece and Rome for mining purposes. The modern joint-stock company was preceded by several types: the "regulated" company, which was little more than a trade guild; the chartered joint-stock company; and the unincorporated joint-stock company formed under common law, which was a great partnership issuing transferable shares. During the latter part of the Middle Ages associations of merchants banded together for trading purposes; these regulated companies were merely protective guilds enjoying monopolies in certain regions and each merchant carried on business separately. The earliest English joint-stock company, in which each member held shares, seems to have been the

[7] Shockley, W. H., and Cranston, R. E., "The Organization of Mining Companies," *Trans. International Engineering Congress,* San Francisco, 1915.

Merchant Adventurers of England, formed in 1390 by charter from Richard II.

The mining industry shared in the prosperity of Queen Elizabeth's reign, during which time a royal grant was given to Daniel Hogstetter, a German, to engage in mining in eight English counties. Such a grant was probably given to encourage men of Germanic race to bring to the realm their great skill in mining and metallurgy. These letters patent were subsequently confirmed by a charter by which

> the Queen [May 28, in the 10th year of her Reign] erects a Corporation, of which William Earl of Pembroke was the first Governour, and Robert Earl of Leicester, James Lord Monjoy, Sir William Cecill Assistants, and many other Persons of Qualitie joyned, consisting in all of 24 Persons and as many Shares, and those Shares subdividable into half and quarter parts, so that they might consist of 96 Persons, their Votes being according to the proportion they had of Shares.[8]

This group was called the Society for the Mines Royal, and it is said that "these Persons thus incorporated by a joynt Stock wrought several Mines with good success." This society continued its operations until 1852, when the charter was allowed to lapse. Another grant, made at the same time as that for the Mines Royal, provided for the formation of a corporation known as the Society for the Mineral and Battery Works. These charters gave liberal powers of self-government, stated the royalty the Queen was to receive, and granted very extensive rights, among them the privilege of opening mines, in any part of the wide area mentioned, without paying fees or damages to the owner of the property.

Chartered companies, however, suffered from several disadvantages, while joint-stock companies under common law grew up rapidly. Joint-stock companies had their origin in the demands of growing industry for greater capital and in the desire of those men who had accumulated money to invest it at a profit. Such companies enabled large numbers of people to invest money formerly hoarded. The sum of such hoards about 1700 was supposed to be very large; it is reported that the father of the poet Pope kept twenty thousand pounds in his strong-box. The word "stock-jobber" was first used in London about 1688, and hence it must have been about the same time that the joint-stock company became of lively interest to all who had money to invest.

[8] Pettus, Sir John, *History, Laws, and Places of the Chief Mines and Mineral Works in England, Wales, and the English Pale in Ireland,* London, 1670, p. 21.

In the short space of four years a crowd of companies, every one of which confidently held out to the subscribers the hope of immense gains, sprang into existence; the Insurance Company, the Paper Company, the Lutestring Company, the Pearl Fishery Company, the Glass Bottle Company, the Alum Company, the Blythe Coal Company, the Swordblade Company. . . . . There was a Copper Company, which proposed to explore the mines of England, and held out a hope that they would prove not less valuable than those of Potosí.[9]

Nearly all of these companies formed at the beginning of the eighteenth century were failures. Adam Smith[10] quotes the Abbé Morellet, writing before 1776, as giving a list of fifty-five joint-stock companies for foreign trade that had been established in various parts of Europe since the year 1600, all of which failed because of mismanagement. The most notorious failure was that of the chartered South Sea Company, which at one time had £33,800,000 trading capital and the collapse of which led to the "Bubble" Act of 1719, providing that unincorporated companies could not sell transferable stock. This act failed of its purpose and was finally replaced in 1862 by an act which prohibited all associations of more than twenty persons from carrying on business without registering and incorporating. At present the principle of limited liability has been worked out, so that the old unlimited company is virtually extinct.

Adam Smith, writing in 1776, saw but little future for the joint-stock company except for banking, insurance, and canal building. Another author wrote in 1830 that joint-stock company management was characterized by negligence and confusion, and that companies trying to make a success of American mining under such organization were meeting with formidable obstacles. However, the joint-stock company as an instrument of modern commerce has developed, with the aid of cheap means of transportation and communication, to an unimagined degree, by which it is possible for a company numbering its shareholders by hundreds of thousands and its shares by millions to operate mines in many corners of the world. This, it is clear, would be inconceivable under any more primitive form of organization such as the old cost-book method.

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[9] Macaulay, T. B., *History of England*, chap. 19.

[10] Smith, Adam, *The Wealth of Nations*, Book V, chap. 1.

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Chapter 13

Modern Mining Companies

Modern companies differ greatly in the purposes they attempt to achieve and in the functions they perform, but in general the structure and method of organization of each company is the same no matter whether it is engaged in mining or in some other form of business activity.

STRUCTURE OF MODERN COMPANIES

The word "company" originally signified no more than a group of persons breaking bread together (from *cum panis*). In the United States the word still remains somewhat indefinite; but in the British Isles it is ordinarily used to refer to a joint-stock company registered under legislative act.

British companies.—Associations of more than twenty people are prohibited from organizing a business in the United Kingdom without registering under the provisions of the Companies Act of 1908 and its amendments. This act replaced that of 1862, mentioned in the previous chapter. A clause of the Act of 1908 which is of interest to mining men is that which excepts from its restrictions all companies engaged in working mines within and subject to the jurisdiction of the Stannaries.

A joint-stock company wishing to register must state whether its liability is to be unlimited or limited. The limited company is by far the commoner form and of all schemes for man's co-operative enterprise is best fitted to promote the large undertakings of modern trade, commerce, and industry. The theory of limited liability assumes that every act done, or contract made, by a company in excess of its powers is null and void and that the liability of the shareholder for acts of the officers of the company is limited to no more than the face value of his shares. The abbreviation "Ltd.," which is required by law to appear after the name of the company wherever used, is a continual warning to the world that anyone doing business with the company can collect from it no more than the sum

of capital remaining in its treasury, plus the assets of the company.

The officers of a proposed limited company must present a memorandum of association under the act, stating the following facts: name of company; part of kingdom in which main office is situated; objects of the company; limitation of liability; and amount of share capital divided into shares of fixed amount. The capital thus stated is the *nominal* capital, which differs from the *subscribed* capital, or the aggregate amount agreed to be paid by those who have taken shares. The borrowing power of the company is also usually stated in the memorandum.

After receiving a certificate of incorporation the company formulates articles of association, which comprise the rules and regulations governing the powers and duties of officers and shareholders and stating procedures to be followed. These articles, unlike the memorandum of association, may be altered by vote of the shareholders.

The officers and directors at the time of organization are usually named in the articles and are later elected by the shareholders. Directors have power to manage the business, but are not trustees; they are "commercial men managing a trading concern for the benefit of themselves and the other shareholders." They receive compensation for meeting and transacting all company business. Their responsibility is to the shareholders. If they misapply funds they may be prosecuted for misfeasance, or breach of trust; they may also be prosecuted for issuing a false or fraudulent prospectus.

The company is required to hold a general meeting within three months after beginning business and must hold others at least once a year. These meetings give the stockholder an opportunity to exercise his voting right in the conduct of affairs. Officers are elected, reports made, and other matters dealt with at general meetings.

The proprietorship of the company lies in the body of shareholders, in whom is vested all authority. In addition to voting power the shareholder possesses a number of other rights, chief among these being the right to share in any dividend paid to the class of shareholders to which he belongs, the right to subscribe to any new shares issued, to share in the assets on dissolution, to transfer his shares, and to sue to redress wrongs done to the corporation upon which the directors fraudulently or unreasonably refused to act.

In practice the ratification of the board of directors by the shareholders at the first general meeting is the first step in a long series of delegations of authority; and the control of the company's acts by

the shareholder is actually feeble. Centralization of management is necessary if business operations are to be conducted expeditiously; otherwise a general meeting would have to be called each time any company act was required, and it would be an impossibility to get the large body of shareholders to agree quickly and act as a unit. If the board of directors is a good one, and alive to the needs of the company, delegation of control will be greatly to the shareholder's advantage. The duties of directors are closely regulated in Great Britain; in most states of the United States the limitations are more elastic. Ordinarily in both countries the shareholder does not worry himself with details of administration in normal times. Disaster can therefore overtake a company suddenly, and when under the spur of a critical situation the wishes of the body of joint owners do become articulate it is often too late to save more than a sorry remnant of the original fund. The risk of becoming a shareholder in a business may be lessened, therefore, if the investor keeps a critical eye on the activities of the officers and attempts to insure the election of directors who have sound technical and financial training in the business.

The ultimate source of authority, then, is the company—that is, the shareholders—which is made articulate and effective through the acts of the board of directors. Authority and responsibility are further delegated to the president or chairman, the manager, and the various divisions of the staff down through the foreman to the lowest rank of laborer.

Other types of company recognized in Great Britain, aside from the joint-stock company, are: (1) The "statutory company," organized to perform public works, and authorized by special act; (2) the "private company," which is an incorporated partnership and has the advantages of permanency, limited liability, and divisibility of proprietorship; and (3) companies not for gain, such as benevolent and fraternal societies which may be incorporated.

Corporations in the United States.—The form of organization in the United States comparable to the British limited company is termed a private corporation. A private corporation is created undeı the laws of one of the states. To incorporate, a group must pay a fee and file signed articles of incorporation setting forth the powers the corporation is to have and the amount of capital to be issued. A corporation formed under the laws of one state may ordinarily do business in other states, subject to some restrictions. The laws of the various states differ greatly in detail, and it is impossible to give

in brief form the diverse practices. State laws differ as to whether one corporation may control another by owning a majority of its stock.

The conduct of modern enterprise in the United States, one believes, would be much facilitated, wastes eliminated, and benefits too numerous to mention attained by a consolidation and unification of present corporation laws. Under the existing system, the incorporator has the choice of organizing under the laws of the state which is most lenient for his purposes and least protective of public interest. The effort required to effect a radical change in legislative practice, however, would be great.

When a certificate of incorporation has been received, by-laws for the regulation of the corporation are formulated and adopted by the stockholders. In general, by-laws cover the same points as do the articles of association of a British company, and the duties and powers of director and stockholder are likewise similar. The corporation is liable for the authorized debts contracted by the officers and in certain states may also be liable for other debts incurred by the directors acting above their authority. Creditors may lay claim to corporate property, but the liability of the stockholder is in most cases limited by the amount of his subscription to the enterprise.

Other types of corporation in the United States are: (1) the public service corporation, which is usually given special privileges and is subject to governmental regulation; (2) the public corporation, which is a term for the government in its business capacity, or corporations set up by the government (such as national banks); and (3) corporations not for gain.

SHARES AND SECURITIES ISSUED BY COMPANIES

All companies and corporations have the power to sell shares, to borrow money, to give security, and to issue negotiable paper.

Shares.—A share of stock is a piece of paper certifying that the owner possesses one of a number of equal parts of the business. The capital stock of a company is the total number of equal shares into which ownership is divided, as set forth in the document of incorporation. The owner of one or more shares is known as a stockholder or shareholder, and is a joint proprietor of the business in the proportion to the whole to which the number of his shares entitles him. An individual may purchase any number of shares, which are transferable.

Very commonly each share has a face value or *par* value of a

fixed amount, in denominations, say, of $1 or $10 or $100. The real value of the share, however, is the amount for which it may be sold. Theoretically, if a man subscribed for one share in a company issuing shares in one-dollar denominations, he would pay the company's treasurer one dollar. In practice, and under the law in most countries, a company can issue its shares for less or for more than their face value. One-dollar shares are sometimes issued at such a great discount that only an ignorant person could imagine that the company was sound and honest; such shares sold at ten cents each and marked "fully paid" are traps for those who think they are getting something for nothing. However, as mining companies are often likely to require more capital than is originally provided, a method sometimes used is to sell partly-paid shares, later calling for the unpaid amount up to the par value. When any portion of this amount is called the shareholder cannot avoid his responsibility even by abandoning his shares. This method differs from the assessable mining shares of western United States, whereby the shares of a defaulting owner are advertised for sale and usually pass into the treasury of the company.

A mining company capitalized at a million dollars may issue share certificates stating, for example, that the certificate shows the owner to possess 100 shares each with a par value of $100. The real meaning of this statement is that the holder of the 100-share certificate owns an undivided one per cent interest in the property; the par value of $100 is meaningless, as far as value is concerned, for each share may be worth anything or nothing on the stock exchange. Recently some of the most prominent companies have been issuing shares with no par value indicated; the certificates simply state, for example, that the number of shares in this company is 3,500,000, of which this certificate represents, say, 350 shares. The owner's interest in this case would also be a one-ten-thousandth part. No-par-value shares may avoid unpleasant discussions with tax collectors, and are not misleading, since they do not represent that either the company or the holder is obligated for any fictitious sum.

A company may issue several types of shares, which may be divided into ordinary or *common* shares, and *preferred* shares, which confer special privileges upon the holder. Preferred shares are frequently issued, with the approval of the ordinary shareholder, to induce investors to subscribe at times when ordinary shares would not attract them, by offering certain rights not enjoyed by the holders of

the common shares. These special terms and preferments offered might include any or all of the following types, which by no means comprise all the variations in preferred shares:

1. "Preferred as to assets." This gives the holder a preferred lien on the assets of the company in case of dissolution, to repay the face value of the share.

2. "Preferred as to dividends but not cumulative." If any profit is earned, this type gives the holder the right to a dividend of the 5, 7, 10, or greater per cent agreed upon before any dividend on common shares is paid.

3. "Cumulative preferred." Such a share is to receive a certain percentage dividend every year and if this is not paid in any year it accumulates until the time when profits are made, when the accumulated dividend is payable. Such a preferred share differs little from a bond, except in the important particular that it cannot be foreclosed.

4. "Ranking preference," or "participating preferred." A preferred share may enjoy the privileges of any of the forms described above, and in addition may rank also as a common share and receive another dividend in that status.

Preferred shares may be unredeemable and continue as long as the company exists, or they may be redeemable by the company at a price. Preferred shares may or may not have a vote. They may sometimes be convertible into common shares paying a much larger percentage dividend. There are endless variations of the preference features. Ordinarily, holders of preferred shares rank after bondholders in their claims against the company, and ahead of holders of common shares. It should not be forgotten that the issuance of preferred shares cannot be made without the approval of the common shareholders; nor can a bond issue be made without the same authorization.

The issues of *founders' shares* and *deferred shares* are methods by which the promoters of a company secure to themselves large profits in case the venture is a decided success. Founders' shares may entitle the holder to take all or a portion of the profits after payment of a 7 or 10 per cent dividend to other shareholders. Deferred shares are a device by which profits over a certain percentage are divided equally between a number of ordinary shares at a high price and a smaller number of deferred shares at a low price. For example, a company capitalized at a million dollars may issue 197,500 ordinary shares at $5 and 50,000 deferred shares at 25 cents, all profits to go to the ordinary shares until they have received

6 per cent, after which profits will be equally divided between both types. If the profit should be $120,000 in any given year, the ordinary shares would receive about 9 per cent on the investment and the deferred shares 243 per cent. When the prospectus is issued the small value of the deferred shares does not impress the investor so forcefully as would a detailed statement of the division of profits.

Aside from issuing common and preferred stock, and various other forms of shares, the company may obtain money by borrowing on a promissory note, or by issuing and selling bonds.

Notes.—The company may borrow money at a bank, giving a promissory note. Or, if the sum is large, it is possible for the company to print and float an issue of a number of notes of various denominations and bearing a certain rate of interest. In many cases the company will place in trust sufficient negotiable security to protect the note-buyers against loss.

Bonds.—A bond, like a note, is a promise to pay a stated sum on a certain date and to pay a specified interest. The bondholder differs from a shareholder in that he is a creditor of the company rather than a part-owner. The bondholder is protected by holding a lien on some sort of property, usually in the form of a mortgage, or one of a series of mortgages. Detachable portions of the bond document, called coupons, are convenient certificates by which to claim the interest at the end of each period.

A "debenture" bond is a form of security more commonly used in Great Britain than in the United States. In England a debenture is an interest-bearing obligation which is termed a "floating charge," and is usually secured by some form of mortgage; the holder can step in and make claims if the security is imperiled. In the United States it means, properly speaking, "merely a claim against the income of the corporation—a claim, moreover, that is secondary to that of any outstanding mortgage bonds. Its claim against net earnings, however, is prior to that of preferred stock."[1]

OBJECTS OF A MINING COMPANY

The objects of a mining company, as given in the document of association, are ordinarily stated at great length, and give the company power to engage in almost every form of business activity. A glance at such a document will reveal several pages of text listing as many as thirty objects. Among the more important of these aims

[1] Moulton, H. G., *The Financial Organization of Society*, p. 157.

may be mentioned the following, abstracted from the memorandum of association of a British mining company:

1. To acquire rights and develop property in a given district for mining purposes, and to exercise all other powers granted the company.

2. To prospect for and develop deposits, and to carry on the necessary operations to render the mineral product salable.

3. To acquire buildings and equipment for conducting operations.

4. To carry on business as land and mine owners, miners, metallurgists, metal workers, builders and contractors, timber merchants, sawmill proprietors, timber growers, engineers, farmers, graziers, horse- and cattle-dealers, coach proprietors, traders, shipowners, ship-brokers, importers and exporters, and to buy, sell, and deal in property of all kinds, and to carry on any other business, manufacturing or otherwise, which the company may think calculated either directly or indirectly to advance its interests.

5. To acquire legal right to real property, patents, privileges, trade-marks, copyrights, and goodwill, and to contract for services.

6. To spend money for exploration and technical advice.

7. To engage in financial operations.

8. To promote and organize other companies to advance the objects of this company, and to deal in securities.

9. To deal in patents, licenses, and secret processes.

10. To acquire other companies, their assets and liabilities, by payment through issuance of securities.

11. To develop or sell any or all of the property and rights of the company.

12. To obtain and sell minerals found on the company's property.

13. To lend money and advance credit.

14. To raise capital by the issuance of securities.

15. To enter into arrangements with governments, companies, and persons, and to obtain and exercise rights and privileges secured.

16. To act as agents for others, and to act for the company through agents, brokers, subcontractors, or others.

17. To pay the expenses incident to the formation of the company.

18. To subscribe to any charitable or insurance fund which may be of benefit to the company or its employees.

19. To dispose of all or part of the undertaking of the company for such consideration as the company may think fit, in particular for the securities of any other company.

TYPES OF MINING COMPANY ACTIVITY

The objects specified in the document of association of most mining companies, it is seen, give them the power to engage in almost every form of business activity. Aside from the general operating companies whose main purpose is the discovery, exploitation, treatment, and sale of mineral products, there are a number of other companies, or syndicates, formed for a more specific purpose. Among these may be mentioned (1) prospecting clubs, (2) search and exploration syndicates, (3) development syndicates, (4) exploration companies, (5) finance syndicates, (6) process companies, and (7) companies allied with mining companies. The mining company itself may also engage in certain legitimate side lines.

Prospecting clubs.—Small groups frequently organize for the purpose of "staking" a prospector and sharing in the development of any claims he may discover. Such groups may be only loosely associated, or they may be more formally organized as a prospecting club, issuing certificates to show that the member has paid a certain amount into the club treasury. Many of these clubs merit condemnation, but if the club is well managed it is an entirely proper form of mining endeavor.

The manager of a prospecting club should be a good mining engineer with executive ability and business experience, residing in the central camp of a promising mining district. He should keep records of all prospecting in the vicinity, and should put himself on friendly terms with prospectors, so that if one of these men discovers a likely prospect, he will be glad to offer it first to one who has always acted in a neighborly manner. In this way most of the prospectors in a district may be said to be working for the club.

The prospecting club should of course have sufficient membership to furnish money enough to take an option and do some development work with a view to selling the property at a profit if it proves to be promising.

Search and exploration syndicates.—Search syndicates, like prospecting clubs, deal mainly with mines in the early stages of discovery and development; but they have a stronger type of organization and a firmer financial backing. Such a syndicate should have capital sufficient to carry on a campaign over several years.

In the ordinary sense, a "syndicate" is an association or company, usually of a limited group of people, contributing capital or service

to carry out a particular purpose. Thousands of small groups of this kind are formed for specific purposes, although many of their schemes never result in profit; but so strong is the lure of "Big Bonanza" that the same people time after time put their money into such speculations. The engineer-promoter who heads such an organization, engaging legitimately in the search for new mines, can continue to hold his followers as long as he gives them "a run for their money"; otherwise he may find himself deserted and, possibly, entangled with the law. It may be said that it is unwise for anyone of small means to risk his money in such speculative ventures, which are better left to those who can afford to lose, without suffering, the entire capital contributed.

Syndicates are commonly of short duration, and are liquidated as soon as it is known what the outcome of an enterprise is to be. If the syndicate is a failure, it is becomingly interred; if it is successful, it may be converted into an operating company by sale or reorganization.

The search syndicate often has its headquarters in some large city of a mining district. A young engineer with practical experience is sent to scout for promising properties. His activities should be identical with those of the manager of the prospecting club. He will be called upon to make many small examinations and to sift through hundreds of dog-eared reports on obviously worthless properties. Although most of these prospects may be condemned out of hand, there is at least one known case of a good mine that was hawked about for years, acquiring a bad reputation, until it was taken over by a British company and subsequently paid large profits. The reopening of abandoned mines is another possibility which should not be overlooked by the scout; experience has shown that many of these are worthy of careful study. Advances in methods of transportation and metallurgy may render abandoned mines, and even tailings and slag heaps, of great value.

If preliminary examination by the scout is favorable he may be called upon to conduct a more experienced engineer to the field for an extended survey and report. Search syndicates should endeavor to obtain long-term options in order to do necessary development work and make a painstaking sampling and examination of the property.

An exploration syndicate is made up of a group of people who organize for the purpose of engaging an intelligent prospector or young engineer-geologist, outfitting him with transportation and

sampling equipment, and sending him to the mining districts to prospect and to investigate likely claims. Several important mines have been acquired by this method. This is a legitimate form of mining enterprise if conducted honestly, and offers an opportunity for those who wish to speculate in mining. It offers more thrills and greater chances of success than does the purchase of much-advertised ten-cent shares in shady mining companies. In the prospecting syndicate, speculators have at least a million-to-one chance; in the dishonest mining company they have none.

Development syndicates.—The development syndicate does not differ fundamentally from those previously described, except that it has, and must have, more money to spend and is able to carry on larger operations. Most of the capital is usually spent in the development of properties acquired by option on the advice of a scout, confirmed by that of a more experienced engineer. Enough equipment should be erected to carry out the plan of development in the shortest possible time, consistent with moderate overhead costs, but the equipment should not be so expensive that complete abandonment would cripple the company. The manager of these operations must follow the ore with a keen eye and study the economic geology of the deposit hourly and daily as each new face is exposed; records of sampling and assaying should be kept as part of the evidence that may lead to the sale of the property to an operating company.

Exploration companies.—An exploration company is a glorified prospecting and development syndicate, with large financial resources that enable it to maintain a considerable staff and carry on simultaneous operations in many fields. Powerful exploration companies are at times the recipients of governmental concessions which lead not only to mining but to the opening of colonial possessions by railways, steamship lines, and other industrial undertakings.

It is true that very few of the large exploration companies have been as successful as their fabulous expenditures and far-flung operations would indicate. The causes of magnificent failures by large exploration companies as compared with the successes of smaller enterprises might be traced to the factors of huge overhead expenses for offices, staff, and promotion, and the reluctance to abandon a project on which much money has been spent. Not infrequently such companies attempt to recoup losses in mining ventures by financing other business enterprises in no way allied to mining, with a mournful result. On the other hand, the success of companies which take

over only properties having a considerable amount of developed ore makes one believe that it might be the best policy for an exploration company to spend its funds in attempts to exploit several small but worthy prospects rather than to dissipate this capital in seeking an ideal mine.

Finance syndicates.—A finance syndicate or company is formed for the purpose of supplying capital for promising businesses. The capital may be a few thousand dollars or several millions. At a favorable opportunity, usually in the early stages of some mining venture, this money is invested in the undertaking. For instance, a company developing a worthy prospect may have expended all the initial capital raised and, rather than face reorganization or call further upon the shareholders, might be glad to have the finance company come into the business on bedrock terms, or to offer as an inducement an option on a block of shares for a long period at a low price. If the enterprise turns out well, the finance company can then exercise its option at a good profit. The sound policy for such a company is to put a few eggs into each of several baskets.

The finance syndicate offers a convenient and reputable means for the engineer to participate in a business with which he may have a professional connection. If a few associated engineers form such a small finance company at the time when they are prosperous enough to risk a part of their fortunes, this syndicate can take part in almost any phase of the financial activity of the companies for which they are working. This participation is free from criticism so long as it is carried on openly and the connection is avowed at any time when the engineer's advice and his desires may be said to march side by side. It is a recommendation to a business that the engineer connected with it is willing to invest his hard-earned dollars in the same venture in which he is advising others to invest.

At least the manager of a finance syndicate should be alert and fully informed. Best of all, every director and shareholder should take a personal interest in the activities of the group. Mining finance is not an enterprise where inattention and preoccupation will increase returns.

A large finance syndicate is commonly organized for some special purpose, such as raising money for the erection of larger equipment needed by some mining or metallurgical company. Through such an organization, directors and officers of a business who may be prohibited by law from personally engaging in underwriting or other financial activities may take part in furnishing capital for their

company, since their interest is publicly avowed. Such a syndicate may legitimately and ethically underwrite the shares of the main company, advance money in return for options, and act generally as a financial feeder for the growing business.

A finance syndicate or company will in time accumulate a large number of mining shares. It can either declare these as a dividend and so distribute them to the shareholders, or it can keep them in the treasury until profits are won and the money is available for dividends. A prosperous finance syndicate will sometimes declare no dividends but will for a limited time reinvest in other ventures whatever profit is made.

Process companies.—Some of the inventions of the nineteenth and twentieth centuries have produced very large profits under the monopolies granted by patent, so large that a horde of companies, inspired by these successes, are continually being formed to exploit patented processes. Many of these have some bearing on mining and metallurgy.

A great number of these inventions are obviously impracticable. Some are fakes, promoted for fraudulent purposes. There is also a large list of supposedly new inventions that are ultimately found to have been anticipated; and any engineer who has anything to do with the early stages in the formation of a process company should insist that before any other commitments are made the question of anticipation of patents should be sifted to the bottom. All other patents in the same field should be studied, and if the patent to be exploited does not tower over all others in point of uniqueness—if there is any suspicion of anticipation—it should be abandoned, thus saving time and money and avoiding trouble; for it has become a byword that to buy a patent is to buy a lawsuit.

Even if the invention is obviously sound and free from possible litigation—and metallurgical inventions unattended by litigation are few indeed—it must be shown to have wide application and to effect great saving in use. For such a process to be demonstrated a very large sum of money will be needed for building trial plants, for tearing down and rebuilding, and for maintaining early operations. Mining companies are slow to spend money on undemonstrated inventions, and this conservatism is amply justified by experience; therefore, if the process company wishes to put its method into commercial operation it must expect to be asked to bear most of the expense of proving the utility of the invention.

If the process will stand the most ingenious tests of search, com-

parison, and analysis that can be devised it is of course a legitimate business within the professional sphere of the engineer. A sound technical staff, a good research laboratory, testing works, and an advertising department are necessary adjuncts to such a company. The life of a patent is relatively short, and to make it profitable it must derive income through wide application rather than through high royalties. The policy of "all the traffic will bear" will not serve in such a case; this policy will invite a shoal of infringers, and the resultant vexations, litigation, and expense will soon eat up all possible profits.

Companies allied with mining companies.—Many companies not directly engaged in mining may depend on the mining industry for support, either by furnishing the mining company with supplies or services or by handling the mineral product. The most important of these is the smelting and refining company, whose chief purpose, although it may own and operate mines, is the metallurgical treatment of purchased ores and concentrates.

The metallurgical plant must be strategically situated with regard to the geographic and economic factors of supply of ore and fluxes, fuel, water, labor, and transportation facilities. Failures caused by wrongly evaluating these factors may be cited. Dozens of abandoned zinc smelters in Kansas show that the availability of cheap fuel, in the form of natural gas, was overestimated; this was an ideal fuel, but it did not last long, and wasteful methods hastened the day of exhaustion. Most of the plants were in poor position to be converted into coal-using plants, because of expensive transportation.

Good local markets for the metal product will cut costs, as will efforts to encourage the development of local industries to use important by-products such as sulphuric acid.

In the location of metallurgical works attention must be given to the probable effects of smelter fumes on industries already established in the vicinity. This form of trouble has been harassing smelters in the United States since 1796. It would seem unnecessary to issue a warning not to build a lead smelter in a rich fruit district or a copper smelter in an intensely cultivated tobacco-raising area, but both have been done. As a result, a flood of damage suits, under which the company was blamed for the effects of drought, bad care, or insect pests, left one smelting company a large, though unwilling, producer of tobacco. The company seeking to locate a treatment works should give more than a thought to the possible activities of

the "smoke farmer," as the agriculturist is called whose chief crop is a suit for damages.

A metallurgical company must have the best technical advice obtainable, and should maintain an active research laboratory. It should encourage in every way the growth of mining in its vicinity and might allow favorable terms to industries utilizing the by-products of treatment operations. Its aim should be to build up good-will founded on accuracy, skill, and fair dealing.

Side lines for mining companies.—A number of activities not directly connected with the extraction of ore are listed in the document of association of metal mining companies, and all of these may be legitimate side lines for company enterprise. Aside from the exploitation of its main product, it may engage in the mining of other metals by dredge and placer methods; coal mining; petroleum operations; the production of valuable non-metals; perhaps the manufacture of cement; and even the production of building stone, clay, sand, and road-metal. It may of course establish its own treatment works and perform custom smelting. It may build railways to connect with main lines, or acquire timber lands and erect lumber mills to supply the needs of the mine and the mining community. Care must be taken, however, to make sure that no side line, such as the operation of company stores, interferes with the progress or goodwill of the main business, and that minor activities are not scattered so much that the advantages of close supervision are sacrificed.

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Chapter 14

The Promotion of Mining Enterprises

The organization of a new enterprise is commonly the work of a single individual, one endowed with the imagination to conceive of the enterprise as a successful reality, with enthusiasm sufficient to enlist capital in the creation of a new business unit through which to put his plan into operation, and with such qualities of leadership as will enable him to bring into agreement the varied interests of the different groups that must co-operate if success in a business venture is to be realized. Such a person is termed a promoter.

The promotion of a project is almost synonymous with "organization" as used in these chapters. It must be preceded by research, invention, and valuation. Its function in the economic scheme of things is to bridge the gap between the first conception of a project and the actual operation and production, i.e., to bridge the gap between a human need and the satisfaction of the need. Although the promoter may sometimes continue his association with a venture after successful operation is an established fact, he then ceases to be an organizer and becomes in reality a manager.

At several stages in the development of a mine there will arise a need for outside capital. There are several recognized means by which the promoter may obtain this financial backing. A number of more dubious practices have also arisen, designed to enrich unscrupulous men whose purpose it is to promote their own fortunes rather than to advance the mining industry or the interests of their associates. This chapter will attempt to describe the various types of promoters and to discuss the financing or sale of mining properties, the floating of shares in new mining companies, and other legitimate fields of promotional endeavor.

THE PROMOTER

The risks and difficulties of company promoting have in the past furnished an opening for the activities of dishonest individuals who have exploited the gambling instincts of a gullible and avaricious

public, so that the term "promoter" has fallen upon evil days. In fact, it is almost as damning to call a man a promoter as to call him a politician. Although it is quite easy to refer to members of this important class by better-sounding terms, such as "organizer," "entrepreneur," or perhaps even "promotician," there seems to be no reason why the original good old English word need be discarded. When it is intended in these pages to connote the type of promoter that does all his mining in the pocketbooks of deluded investors, some qualified term, such as "shady" promoter, will be used, much as one would speak of a shyster lawyer, a quack doctor, or a yellow journalist. It is harsh to stigmatize a group which performs a valuable service in our civilization with the opprobrium due its most unworthy members. "Company-promoting is no longer a synonym for dishonesty and legalized chicanery. It is recognized as an essential cog in the wheel of financial machinery."[1]

The ideal promoter, then, is a man who possesses the qualities of imagination, enthusiasm, and leadership and who sincerely believes that the venture he is sponsoring can be organized to perform a worthy and useful function in modern industry. He should know the sources of capital, and be able to reconcile and consolidate tactfully the interests of all co-operating groups. He possesses all available information concerning the value of the enterprise, conceives a logical plan of development, and is trained in the legal, commercial, and financial methods of forming a stable organization to carry it into operation. He is willing to stake his time, talents, credit, reputation, and effort upon the possible success of the undertaking, and not infrequently contributes some capital of his own. Since his risk is great, he naturally expects a commensurate profit for himself; but "the fact that the promoter's chief motive is the hope of a liberal return from his risk and effort should in no way cloud the fact that he has performed an indispensable and difficult work in creating a business mechanism which will convert capital into service desired by the community or by the people at large."[2] His chance of success will be greatly advanced if he is familiar with the technology of the field in which he is working—in other words, if he is himself a mining man.

The owner as promoter.—The owner of a mining property or the inventor of a patented process may aspire to keep all profits to him-

[1] *Encyclopedia Britannica,* Fourteenth Edition, article, "Company-Promoting."
[2] Fish, J. C. L., *Engineering Economics,* 2d ed., p. 118.

self by performing the functions of the promoter. Such a procedure is seldom advisable. Both the prospector and the inventor are commonly of the research type of mind, accustomed to working secretly and alone, unfamiliar with methods of raising capital, and frequently harboring preposterous ideas of the worth of their properties. Such an attitude is not conducive to the securing of capital to finance a large undertaking, to the organization of a co-operative enterprise, or to its management.

The amateur promoter.—Neither can it be expected that a person inexperienced either in practical mining or in finance will make any great success in promotional work. Those men whose names are prominent in other fields and who lend their names to schemes the soundness of which they are not qualified to judge must expect to be criticized, as was the son of a prominent American author who, himself a literary man, devoted his enthusiastic pen to the selling of stock in a mine near a well-known Western district.[3]

The shady promoter.—The "get-rich-quick" type of promoter, putting up an imposing front and reeling off glowing and magniloquent phrases, is a familiar figure in cartoons and in fiction; and, unfortunately, he and his kind have not yet disappeared from the financial scene. The crooked promoter and dealer in shares was not unknown as far back as the middle of the sixteenth century, as shown by this quotation from Agricola:

> For to speak of nothing else, but only of those deceits which are practiced in buying and selling, it is said they either advertise the veins with false and imaginary praises, so that they can sell the shares in the mines at one-half more than they are worth, or on the contrary, they sometimes detract from the estimate of them so that they can buy shares for a small price.[4]

It is not always easy to distinguish between the promoter with honest intentions who hopes to develop a property and the dishonest promoter who uses a "wildcat" mine merely as a counter in the game of selling worthless shares and manipulating stock transactions. The wiles of the latter class, operating within or outside the margins of the law, are too numerous to detail here; many examples of their cunning may be found in the columns of the technical press. The intentionally dishonest promoter is in the business of selling valueless pieces of paper. He makes no contribution to mining, and by putting

[3] See "The Temagami-Cobalt Mines, Ltd.," (edit.) *Engin. Min. Jour.*, Sept. 19, 1908, pp. 586–87; and "The Hawthorne Verdict," (edit.) March 22, 1913, p. 629.

[4] *De Re Metallica*, p. 21.

the sale of mining shares in bad odor he discourages the investment of capital in ventures that have legitimate chances of success. He may have had a claim located for him on the fringes of a well-known mining district, but his operations are conducted from a city office. Here he proceeds to put together a grandiloquent prospectus, complete with photographs—lifted from the technical press—of shafts and mills falsely labeled with the name of his hypothetical mine, and high-pressure appeals to "act now," accompanied by eulogies of himself and his mine, references to the fortunes that have been made in stock-promotion schemes of all kinds, descriptions of well-known rich mines in the district (although his mine may be twenty miles away), and an optimistic and frequently nonsensical discussion of the geology of the district in which he claims to operate, written by an alleged engineer. This prospectus is sent out to a "sucker list" composed of the names of people who have in the past been attracted by the advertisements of the type of wildcat company offering "one-dollar shares at three cents, the shares to advance to ten cents Friday." He also inserts notices in venal periodicals, and may even maintain a staff of salesmen who are adept at playing upon the greed of those who wish to get rich overnight.

The earmarks of a dubious stock-selling drive are not often mistaken by the trained eye; in fact, it is a safe maxim never to purchase shares in any highly advertised promotion. Some typical selling "literature" follows:

> This adjoins the A—— property, is a continuation of the same deposit, A—— shares sold at $4 when they were brought out, now they are above $40.00.

> Your Fortune is in Reading this Advertisement.
>
> The biggest proposition ever offered to Womankind and Mankind in the History of the Mining World.
>
> Stock is $1 per share and never again will you have the opportunity of buying it for any less after this association is completed. Your fortune is before you; your brains and your judgment is your action. The time is now—today—this minute. Be sure you read every word.[5]

> When your children, or your grandchildren ask why you, too, did not share in the profits of this, the world's greatest oil boom—*what will your answer be?*[6]

> This substantiated evidence will emblazon Rochester Merger Mines throughout America, and galvanize into action the public, who will rivet

[5] "One Reason Why Mining Languishes in Colorado," (edit.) *Engin. Min. Jour.*, Oct. 30, 1920, p. 849.

[6] Moulton, H. G., *The Financial Organization of Society*, p. 192.

their support to Merger shares with "jack-hammer" speed the minute this corroborative mine data is forthcoming—sending the price thermometer to blood heat.[7]

> When it is taken into consideration, that the upwards of forty-four billion tons of ore on this property, multiplied by six dollars, amounts to the stupendous figure of more than two hundred and sixty-four billion dollars, it will be readily seen that this property is capable of yielding sufficient wealth to pay off the national debt several times over. . . . . Of all the world's large gold ore depositions thus far discovered, the Arriba is by far the largest, the most colossal, and gigantic that has ever been recorded in the history of mines. The Arriba, in the mining world, is comparable only to the Grand Canyon of Arizona in the scenic world.[8]

From a newspaper advertisement for shares in a Utah silver property has been unearthed this geologic gem, the only information given to enable a possible investor to determine the value of the shares:

> The formation on Chloride Canyon belongs to the miocene and quartinary ages, with pelsoaic intermingled. The porphyry lies on the east and has been wholly undisturbed, while the rhyolite on the west seems to have had some heavy movements. The porphyry is magnifurious, granite porphyry.[9]

The way of the flagrantly fraudulent promoter is not always easy, and several of the most active are languishing in the penitentiary for using the mails with intent to defraud. A larger class are the "semi-dishonest" promoters who acquire actual mines, perform development work, and go through the motions of mining. This type of promoter likes to secure a mine in proximity to some well-known rich property, thus giving some color to his enthusiasm. A third class of objectionable promoters are the honest but ignorant; these men deceive themselves and thereby unintentionally deceive others. A fourth class might be termed the visionaries, who do not intend to defraud but whose ideas are wildly impracticable. These latter three classes are not easily assailed, for they can report development work as favorable and it is almost impossible to prove that it is not. If they did no work at all they could be prosecuted.

Curbs on the dishonest promoters.—Aside from the federal government's activities to prevent use of the mails for fraudulent purposes, many of the states have passed so-called "blue sky" laws,

[7] Dewing, A. S., *The Financial Policy of Corporations*, Vol. 2, p. 161.

[8] "A Rich Superlative in Stock Selling Appeals," (edit.) *Engin. Min. Jour.*, Dec. 29, 1928, p. 1006.

[9] "Metalliferous and Also Argentiferous," (edit.) *Engin. Min. Jour.*, March 20, 1920, p. 687.

which make it a criminal offense to sell stock without a license from a public official, who is charged with refusing to grant this license if he believes the plan of incorporation to be illegal, fraudulent, or unfair. Several writers have felt that such paternalistic legislation has hindered the mining industry by imposing a further barrier to the development of small prospects, at the same time charging that it does not prevent fraudulent stock operations. The other side of the argument is represented by this statement from a commissioner of corporations for California, commenting on a list of oil and petroleum companies that have offered their shares for sale without complying with the law:

> The securities offered for sale by some of these companies may form an attractive investment. Others may be of doubtful value, and some of them may be entirely worthless. There is no intent on the part of the commissioner to limit the right of people to engage in speculative enterprises as long as they are fairly conceived and honestly conducted. However, the investing public has the right to be fairly informed of the hazards which may be encountered and to have such regulations enforced as will protect it from fraudulent schemes and unprincipled schemers.[10]

It might also be pointed out that the "blue sky" legislation gives the investor a false sense of security, and that it is difficult to make clear the fact that the state, in granting permission to sell shares in a certain venture, does not thereby certify to the good character of the offerings and does not stand behind the legitimacy of the investment. For these reasons, "blue sky" laws have in some states given way to fraud laws, under which only those new securities that appear to be fraudulent are examined by state officials. Such laws are much less burdensome to the honest promoter of a small prospect.

The above comments also apply to the Federal Securities Act of June 1933, which requires that companies floating stock and bond issues must register a complete account of the company's affairs, including all material facts (compare with list on page 331), and which makes directors liable for loss incurred by a buyer through omission or misstatement of material facts. The latter practice has been the rule in England for some time.

The unscrupulous promoter and the crooked director—both of the same ilk—cannot well carry out their nefarious designs without the collusion of a complaisant (a much uglier adjective might be used) engineer. Indeed, many times in the past the engineer has by

[10] "Protection to Investors in Oil and Mining Stocks," *Engin. Min. Jour.*, Aug. 30, 1919, p. 343.

virtue of his position been enabled to protect public interest by protesting against unethical practices. Some engineers have taken even a more serious view of their obligations and have fought long and bitter fights against unscrupulous methods. Professional societies have extended their ethical codes to prohibit participation in doubtful promotional schemes, and the columns of the general and technical press are always open to discussion of flagrant violations of professional conduct. All of these agencies have done much to puncture the bubbles of fraudulent promoters.

The public demands a high ethical standard of mining engineers and is not disposed to be lenient toward those who issue unduly optimistic reports on prospects of little value. An editorial on two recent cases pictures the consequences of such complaisance:

> Only a few months ago a New York jury convicted George Graham Rice and his associates for use of the mails with intent to defraud in the Idaho Copper case. In that trial, Rice's consulting mining engineer was let off with a warning, but there is no doubt that his professional reputation suffered considerably by his association. In the Canario case, just ended after a six weeks' trial, the mining engineer employed by the guilty company was not so fortunate and was convicted of conspiracy to defraud. . . . . If any members of the fraternity in future are tempted by a salary of anything up to a hundred thousand dollars a year from a company that bears the earmarks of a crooked promotion, let them remember that a jail sentence, a fine, and complete loss of professional reputation are likely to ensue. . . . . But more than all else they lose the social regard of their fellow men as friends and useful members of society, and when an engineer loses that, there is little more to live for.[11]

The engineer-promoter.—No better guide to the advancement of worthy mine finance could be found than an engineer who possesses business and executive ability in addition to his training in scientific management and technology; and it is becoming increasingly common for such men to take a more active part in those promotional fields that have in the past deserved to be described as "mining without engineers." Engineers possessing such ability cannot give too serious consideration to the possibility of broadening their activities to include the financing and sale of promising mining properties. Men of high repute, of the caliber of Daniel C. Jackling, J. Parke Channing, John Hays Hammond, Hennen Jennings, Charles Butters, Frederick W. Bradley, and Herbert Hoover, have shown the way, and have proved that it is possible to carry over into promotional

[11] "A Warning to Mining Engineers," (edit.) *Engin. Min. Jour.*, April 6, 1929, p. 546.

efforts the high ethical code that governs the other activities of the engineer. That no subscriber in shares in enterprises sponsored by these men has had any reason to complain of his treatment is evidenced by the fact that most of these investors have followed such leaders in venture after venture. A loyal following is the greatest asset a mine promoter can possess; and it is also true that an investor will do well to choose the shares of companies with which are connected men of unquestioned honesty, discernment, and technical skill. The investor cannot ordinarily examine a mine himself, nor could he evaluate the chances of its success if he could; but it is not difficult for him to ally his interests with those of engineers of known reputation.

Every profession or business one can name, be it that of promoter, banker, doctor, engineer, grocer, butcher, lawyer, preacher, or any other of the activities of men and women, has in its ranks not only the noble, true, honest, and capable, but also a few of the false, dishonest, incapable, and ignoble. The word engineer itself is misused as well as the word promoter. The word engineer is used to cover the janitor, the jerry plumber, and the locomotive driver. The word doctor is misused to cover the doctor of philosophy, the veterinary, the chiropodist, and the tree doctor. In the course of the development of language there are certain nuances to which we are oblivious until our attention is called to them by a paradox. One who does not understand these things and misuses the word promoter would say that engineers who have taken up promotion are not promoters—because they are honest. These engineer-promoters sometimes make a profit on their efforts. They all put their own money into their enterprises, as much as they can afford, on the same terms as the general public; and they also receive some extra reward for their engineering and promoting abilities.

Let us conclude this section by saying that if the engineer is one who dreams dreams and makes them come true, the same thing can be said of a promoter, using the word here in its best sense. These men were all engaged in a hunt for new mines; they found new mines and they opened and developed and equipped these mines; they found capital for this development and equipment among their friends and from the general public; they organized the companies necessary for the co-operative effort; and they managed the mines and the production of the metal and so supplied an insistent human need. This is promotion allied with engineering, and they were engineer-promoters. All or part of these functions are a quite proper activity for

an engineer. So far from disclaiming that they are in the business of promotion these engineers and many others not only are proud of their promotion activities but dignify the profession of promotion.

THE FINANCING OF MINES

Few are the mines that finance their own development from the grass-roots. Most owners of mining property must at one time or another seek outside capital to advance development and carry on production. The means by which this financing may be done serve to show the function of the promoter.

It would be needless to say that a man should first possess a mine before he attempts to sell it were it not for the fact that hundreds of mining companies have been organized on the flimsiest foundations. Indeed, during the West Australian mining boom shares in an imaginary mine were sold by a duly organized company to the extent of £100,000; afterward the company acquired a mine and the reports and documents were "adjusted" to suit the case. But assuming that a promising prospect exists and is to be sold either outright or by shares, what methods may be used to finance the enterprise?

Bank loans.—Banks are in the business of lending money, and their assistance is frequently sought in the promotion of private corporations offering security of one sort or another. However, it is more than likely that the uncertainty of success in a new mining venture will preclude the securing of capital from investment banks and other agencies controlling large sums, and the promoter must seek other sources of capital.

Syndicates.—The mine owner may be able to interest capitalists in the formation of a syndicate to develop his property, arranging to exchange part of his ownership for an interest in any profits which the syndicate may make.

Sale.—There may be decided advantages to the mine owner in selling his property outright or perhaps retaining a minor interest. Capital is always searching for promising new mines, and large development and operating companies are nearly always willing to pay for them a price representing not only the present value but a fair part of the prospective value of a young mine. By selling, therefore, the owner might place himself in the position that he would attain only after some years of developing the property himself, and the purchase

money would make him a capitalist who could engage in the financing of other mines without the worries and risks of attempting to realize the future value of his only prospect.

One cannot emphasize too strongly the necessity for anyone promoting the sale of a mine to be able to present an accurate and well-written report by a competent engineer who has made an examination under the principles outlined in the first part of this book. Such a report will serve as an excellent introduction to anyone commanding capital. If the seller possesses some capital of his own he can also make a good impression by offering to pay part of the expense of confirming the findings of this report. Another way of showing good faith is to allow the prospective buyer plenty of time for examination.

Representatives of a possible purchaser of a mine will be sure to ask whether or not the owner is willing to take shares as part payment, and any objection to such an arrangement will at once arouse suspicion. Refusal will be taken as evidence that the seller has not sufficient faith in the valuation of the property or that he has overestimated this value, either directly by inflating the reported reserves or indirectly by minimizing the capital required for equipment and development. If, however, the seller does agree to accept shares in payment, he should assure himself that the buyers intend to expend ample capital in the development of the mine. This can be done by dealing only with responsible capitalists with reputations for fairness, and by means of a contract drawn by a competent lawyer.

One thing is certain: the seller cannot both have his cake and eat it. He cannot hope to interest capital by offering less than majority control of his property; if a company is to be formed, the buyer must possess at least 51 per cent of the shares. No person of sound judgment would add to the risk of investing large sums in a mining venture the risk of allowing control of his money to pass into other hands.

Organization of a company.—The commonest method of raising capital to develop a mine, however, is by organizing a company and issuing securities which permit a large number of small investors to contribute the needed funds. The owner may sell his property to the company outright or may retain a block of shares. The regulations under which companies are formed in Great Britain and in the United States have been mentioned in the previous chapter. Here it will be pertinent to discuss the ways in which new mining com-

panies formed under these two systems may attempt to obtain capital by the initial issuance of shares and by calling public attention to the opportunity to invest in the enterprise.

PROMOTION OF A NEW MINING COMPANY

British limited company.—The first step in the sale of a mine in London is to find a promoter who will form a limited company, because direct sale to individual capitalists is almost unknown. The British laws for the protection of the investor are exceedingly strict, and the principal method the promoter uses in order best to conform to all the rules and regulations is to transact all initial business through a small syndicate composed, perhaps, of clerks in his office. This syndicate makes all preliminary contracts governing the acquisition of the property, and later transfers control to a large company, or is expanded into a large company, which sells the shares to the public.

One method of introducing the company to the investing public, which is less used now than before the World War, is by issuing a complete prospectus. The preparation of the prospectus is the work of experts, who state the advantages of subscribing, taking care not to violate the rigid legal restrictions covering such documents. All contracts affecting the company, the promoter, the directors, or their intermediaries must be published in full; for while it is quite legal for all these persons to make a profit in the business such contracts must be made known to the public before they subscribe to the shares, and the taking of hidden profits is sharply punished. One California oil company floated in London had to return £176,000 to the subscribers because of an irregularity in its prospectus.

While the negotiations are being made for the purchase of the property and the prospectus is being prepared, the promoter selects the directors and chairman of the large company to be formed. These persons are supposed to have, and generally do have, a substantial amount of money invested in the company. The favorable report of an engineer must appear in the prospectus, although the name of the engineer often carries less weight with the public than does the roster of directors, bankers, and brokers connected with the enterprise. When the memorandum of association has been certified, and shares may be offered for sale, the prospectus is printed in the newspapers and copies are sent out by mail, with application forms attached. If times are prosperous, the venture promising, the sponsors reputable,

and especially if the mine is in a region fashionable at the time, an over-subscription is likely. In such a case, "letters of regret" are sent to those to whom shares are not allotted and their checks are returned; or perhaps a proportionately smaller number of shares is allotted to each subscriber.

A method frequently used at the present time is that of "introducing" shares in a new company on the stock exchange. During the time between the formation of the company and the listing of its shares on 'Change, public interest is aroused by items in the press, and when the shares are finally listed a market for them has already been created and a number of buyers are ready to begin trading. Investment is invited by an "offer for sale," which is in the form of a letter from the head of the company, reciting the advantages of purchasing shares; but since this offer for sale is not a prospectus it is not required to state the sums paid to intermediaries who have assisted in the formation of the company.

Before a share issue is floated by any company, the directors may take the step of having all or part of the proposed share capital underwritten. A company may resort to underwriting if there is any doubt that the public will subscribe to the issue in full; but in prosperous times the procedure is seldom used. To underwrite an issue the directors approach certain firms of brokers, or mining finance syndicates, or individual capitalists, who agree, for a certain compensation, to guarantee that the shares will be sold, by promising to take over any shares not subscribed for by the public. Remuneration may take the form of a cash payment of 2 per cent to 8 per cent of each share; if all the shares are absorbed by the public, the underwriters are absolved and receive the agreed payment. The remuneration may also take the form of a long-term option on certain blocks of shares at a given price. If the mine is a great success the underwriters can then exercise this option at a time when the market price of the shares will return a profit.

One of the chief differences between British and American methods of floating a share issue is the practice of underwriting. In England the promoters do not resort to underwriting unless money is scarce; but in the United States, generally all shares are in the first instance taken by underwriters, who later sell their shares to the public at a time when a demand, natural or created by advertising, exists.

The profits from stock promotion in London are sometimes very large. In one promotion, where all shares were subscribed, the pro-

moter's profits from a capitalization of £110,000 were £25,000, or more than 20 per cent. But the expenses and risks of promotion may also be great; in one case the cost of promotion was £5,000, and the subscriptions brought in no more than £23. It may be well to repeat a caution already made in chapter 2, that an effort should be made to weed out intermediaries who may attempt to secure a large sum for rendering no greater service than introducing the seller to the promoter or to members of finance syndicates.

It may be imagined that it is no easy task for an American mine owner to float a stock company in England.[12] Even so, there are logical reasons for the legal restrictions imposed, and one might go farther and fare worse, as any American who has attempted to finance a company under French law will agree.

Incorporation of American mining companies.—Small mining companies formed in the earlier stages of development may be incorporated at little expense, and even without the aid of a lawyer. In the boom days of 1905–1906, thousands of these organizations were formed on the Pacific Coast—so many, in fact, that it was difficult to devise an original name that would have some local meaning. Many such companies tried to select a name that would reflect the glory of some famous mine or camp, such as the Divide district: Divide Mining Company, Divide City, Divide Consolidated, Divide Extension, Divide Junior, East Divide, High Divide, Jim's Divide, and Pay Divide.

Company officials are chosen, and steps toward incorporation are taken, under the laws of a state with lenient requirements and low fees. During the past thirty years probably more mining companies have been formed to operate mines in Nevada than in any other state; in the boom days fully 6,000 companies were incorporated, of which at least 5,800 are now defunct. But few of the companies were incorporated under the laws of that state, because lawsuits involving companies of foreign origin (i.e., from another state) could be thrown into the federal courts and thus evade Nevada jurisdiction. South Dakota and Arizona were especially favored by such incorporators.

Actual incorporation was simple. An application was sent by mail to the proper state official, together with money for fees, and in due time a certificate of incorporation was received. Often in such

[12] See Hillman, William, "Company Promotion in London," *Engin. Min. Jour.*, July 6, 1912, pp. 19–21.

cases no lawyer was retained and the total cost of forming the company, including the seal, articles of incorporation, by-laws, share certificates, and account books, might be not more than fifty dollars.

After these preliminaries, the sale of shares could at once begin. Such companies would commonly be capitalized at a million dollars divided into shares with a par value of one dollar. Shares were sold for prices anywhere from a cent to a dollar. Needless to say, very few of these shares ever went to a premium, the most noteworthy exception being the Mohawk of Goldfield, which advanced to a maximum of $20 from an initial price of about ten cents.

The cost of forming important mining companies under the more stringent incorporation laws of some Eastern state may easily total several hundred dollars, including lawyer's fees.

Shares in mining companies cannot usually be sold in the United States by means of a simple offer for sale or by publishing a prospectus, and every known device of promotion is used. Few mining securities are admitted to the New York Stock Exchange, and trading in them is usually carried on in the Curb Market. The operations of stock exchanges will be discussed in the next chapter.

AMOUNT OF CAPITALIZATION

The amount at which a new company is capitalized will have a direct effect upon its chance of success. Suspicion that the company is overcapitalized will drive away support, while if the organizers secure insufficient funds from the initial issue of stock, they are likely to find themselves without money to carry the mine into the producing stage and must undergo a drastic re-financing program.

Overcapitalization.—Evil results will not follow overcapitalization of a company if the capital is in the form of money, for cash can always be returned to the subscribers. Dangerous overcapitalization is due to "watering the stock," in other words, to having too high a proportion of the capitalized value in the form of promoter or intermediary profits. Suppose that to purchase, develop, and equip a mine requires $100,000 and that the mine will pay $30,000 yearly, or 30 per cent on that capitalization. If the promoters of this mine should grossly overcapitalize its stock to the amount of $500,000, and should set aside $400,000 as their profit, only one-fifth of the profits would remain with which to pay the subscribers whose money made the enterprise possible. This portion, $6,000 a year, would return

them no more than 6 per cent, and a 6 per cent mining share is a poor thing indeed.

In determining the amount of capitalization the engineer is the final arbiter—if he wishes to be. He can prevent any gross inflation of value by appealing to the public over his own signature, stating the facts as he finds them. This course was pursued by a noted American engineer who objected to the overcapitalization of some South African mines that he had examined. His name thereafter was anathema to a group of London promoters who claimed that the whole duty of a mining engineer was to report the facts and to leave all financial considerations to others. But the investing public and the engineering profession are coming to recognize that there is no reason why mining economy should be presumed to lie beyond the province of the engineer, and many reasons why it should not.

Insufficient capital.—To make a success of a mining venture it is necessary to equip and develop the property to the point of production, and in many cases this requires millions of dollars. From this point of view, most of the productive mines of today have at various stages in their history been failures, and have found themselves in the predicament of lacking money with which to continue operations. This hand-to-mouth sort of mining is uneconomical; it favors "picking the eyes out," skimping on supplies and labor, and using cheap and sometimes dangerous machinery, and otherwise necessitates slipshod development methods. Although engineering mistakes are not always the cause of insufficient capital for development, enough cases of the sort have arisen to lead the engineer to make every effort to avoid such fiascos.

The causes of the need for re-financing a company are legion, but some of the most prominent may be mentioned:

1. The organizers, unable to sell the full issue of shares, may have unwisely resolved to carry on with what money they could raise.

2. The organizers may not have consulted an engineer with regard to the financial program, or may have chosen to disregard such advice on capital requirements.

3. Errors in the valuation process, or unjustified optimism in the engineer's examination, may have resulted in underestimation of the cost of development and equipment.

4. The mine may have failed to respond to the hope that ore taken out in development would help finance the undertaking.

5. A process, or a scheme of management, may have failed to come up to expectations in saving costs.

6. Delay or unforeseen difficulties may have impeded development and eaten up capital in overhead expenses.

7. Improper administration of finances may have been responsible for waste and extravagance.

8. General optimism, the hope that a streak of luck will pull the venture out of the morass as time goes on, is the cause of many failures. The whole atmosphere of mining is an encouragement to gamble against the future, and the miner hopes, as he says, to "get his tail through the door"; but too often the door swings shut and a re-financing program is the only way of escape.

Reorganization.—In such a case, if more money cannot be obtained, all previous expenditures for development and equipment go for naught and all money and effort is lost. The engineer almost always bears the brunt of criticism and is frequently dismissed; new interests step in and take control, or a new issue of stocks or bonds is floated; a finance syndicate may be organized as a rescue expedition, in the hope of making a generous profit. Each time a mine is re-financed, new securities are issued, and the interests of the holders of various classes of securities are more than likely to clash. The owners of the common, or ordinary, shares suffer first and most. A classic example of drastic re-financing was the reorganization of the present General Petroleum Company of California. More money was required, and it was secured by reducing the old bonds to preferred stock, the old preferred stock to common stock, and, with the owners' consent, the old common stock to thin air.

It is not always true that a reorganization results in a change of engineers, but if the original engineer is retained it betokens great confidence on the part of the stockholders. Instances might be given in which an engineer has come before the meeting of shareholders, has explained the causes of the disaster, has taken his share, or more, of the blame, and, if at the same time he has also been able to present a constructive program for pulling the mine out of its difficulties, has carried the whole body of shareholders into an enthusiastic agreement to subscribe a further sum. Such men are worthy of emulation, for to make a mistake is no crime; and when success follows such a *contretemps,* they deserve the credit and profit that they win.

If a new engineer is called in, however, he should take care to profit by his predecessor's mistakes and should insist on funds sufficient to carry the mine into production. A number of engineers have

devoted themselves exclusively to taking over direction at a time of reorganization, among them some extremely able men of high professional rank. Although such engineers have been variously termed "ghouls," "grave-robbers," and "doctors of sick mines," the rehabilitation of wrecked mines is certainly a proper form of engineering effort, and no stigma should attach to the men who perform this too frequently needed service.

CONSOLIDATIONS AND MERGERS

Another field of promotional activity that the engineer is in good position to undertake is that of the consolidation of two or more separate properties under a single management. One encounters many obvious opportunities in which consolidation would make for great improvement from both the economic and engineering points of view. Several adjoining properties, each with a separate plant and management, would greatly lower cost of production by uniting their interests. Again, a company owning a number of mining properties is much more stable financially, for the exhaustion of one deposit will not send it into liquidation.

Frequently the chief obstacle to such consolidations is the rivalry of the controlling groups, who may recognize the advantages of merging but whose interests are hard to reconcile. The promotion of such profitable mergers as can be effected is a legitimate financial endeavor ordinarily resulting in benefits to the public and to the mining industry.

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Chapter 15

The Stock Exchange and the Mining Investor

It might appear at first glance that some understanding of stock exchanges—or market-places where bonds and shares are bought and sold—would be of questionable value to the mining engineer in helping him to perform his duties. However, some knowledge of the workings of these important centers for financial transactions is required if the engineer is to comprehend the background of mining finance. Moreover, since the engineer is many times called upon to advise others upon investments, and is frequently desirous of investing his own capital in projects in his own or other fields, he should know at least the meaning of stock quotations and should be familiar with the ordinary operations in the security market. Many times, too, the report of an engineer to the directors of his company will be the starting-point of a fluctuation in the share market; and at such a time the engineer should be sufficiently informed to be able to define clearly his relationships to the directors, to speculators in the market, to holders of the company's securities, and to the general public. The intention of this chapter is to give a preliminary view of all these topics, which may furnish a point of departure for further study and the accumulation of practical information.

STOCK EXCHANGES

Since men first settled in communities they have met at certain places to barter goods and to trade in one or another commodity. A stock exchange is a market-place where men gather to deal in bonds and shares; and the security market is perhaps the most efficiently organized market in our complex civilization.

Trading is carried on by brokers, who act as agents between buyer and seller and make their livings by commissions on sales. The broker's function is to discover the best market and to act in the best interest of his principal; and thus one who wishes to deal in securities seeks a broker even as one who wishes to buy or sell real estate finds it easier to employ a real estate agent who is in close

touch with that market. Brokers of merchandise have existed from early times, and are mentioned in an act of Parliament under Edward III of England, in the year 1376. Speculative dealing in stocks and bonds is recorded in the reign of William III, about 1690, and the stockbroker first appeared at that time, when the joint-stock companies mentioned in chapter 12 came into prominence. Brokers met to carry on business at one or another of the coffee-houses, and at one of these the association that came to be known as the London Stock Exchange was formed in 1762. From such small beginnings have grown the important financial marts of the world's money capitals.

Stock exchanges of the world.—In all the great commercial centers of the world, stock exchanges have been organized and trading is carried on.

London Stock Exchange. Although the center of the world's greatest financial operations has shifted in latter years from London to New York, the former can still claim pre-eminence in diversity of securities listed and in wide and efficient organization for handling transactions of all kinds. The exchange is not incorporated, but is a voluntary association owning its own building and ruled by elected committees. The membership is large, about 4,000, and admission is obtained by securing the indorsement of three members, who guarantee that the applicant's check is good for £500, and the payment of an initiation fee of the same amount. Failures of brokers in the London Exchange are not uncommon.

Broker-members of the London Stock Exchange are governed by strict rules, and their status is kept quite different from that of the stockjobbers. The broker acts as an agent, seldom as a principal; he does not as a rule buy from a client or sell to a client, but buys or sells on behalf of a client. He executes a client's order through a jobber, whose operations are restricted only by the law of the land. The jobber is not an agent for customers but a dealer who operates on his own account, an expert, buying and selling for speculative profits. He is representative of world supply and demand for the particular security at a given moment and, without knowing whether the broker wishes to buy or to sell, he will quote two prices representing the amounts at which he will trade. For example, if the broker asks a quotation on National War Loan, the jobber may rapidly recite two figures, one at which he will buy, and another, one-eighth or one-quarter of a point higher, at which he will sell. Securities are sold for delivery on the next settling day; usually these

days are a fortnight apart. In the New York Exchange, securities are sold for delivery the following trading day.

New York Stock Exchange. The New York Stock Exchange is the greatest speculative market in the world. It also is an unincorporated, voluntary association, which had its origin shortly after the American Revolution among a group of brokers accustomed to gather under an old buttonwood tree which stood in lower Wall Street. The present building stands in Broad Street on the site occupied by the Exchange since 1865. There are 1,100 members, and a "seat" can be obtained only through purchase from a member or his heirs. Latterly seats have sold as high as $595,000. The new member must also pay an initiation fee, and his credit and integrity must be vouched for by two members. His election must be approved by the committee on admissions.

The Exchange has no charter and is governed by elected officers and a committee of forty-two members holding office for four years. The subsidiary branches of its activities are, however, incorporated, and discharge important functions. These branches are the Stock Clearing Corporation, which serves as a center for deliveries; the New York Quotation Company, whose employees note and immediately report all transactions through a ticker service; the New York Stock Exchange Building Company, which owns and controls the premises; and the New York Stock Exchange Safe Deposit Company, which offers facilities for the safekeeping of millions of dollars' worth of securities.

The New York Exchange does not admit corporations to membership; hence the brokerage firms associated with the Exchange are partnerships of which one partner is a member who transacts business on the floor of the Exchange. The distinction between brokers and jobbers does not exist in the United States, and all members of the Exchange are free to trade with each other and with the public as long as they abide by the constitution and rules.

Five main types of operators are to be found on the floor of the Exchange. These are:

1. The *commission broker,* who buys and sells on order for customers, who may be scattered throughout the country and who are reached by a network of branch commission houses in various cities.

2. The *"two-dollar" broker,* who is not attached to any commission house, but who is ready to assist the commission broker in executing orders, especially during a heavy market. He still retains

his old name, although his commission has been changed to $2.50 for purchasing or selling 100 shares of stock.

3. *Dealers* are operators buying or selling on their own accounts and making their profits from differences in prices rather than from commissions. They perform the functions of the jobbers under the London system. The *odd-lot dealer* buys and sells in amounts less than the required trading unit of 100 shares, and thus enables an investor to purchase a small number of shares.

4. The *floor trader* is a free-lance dealer operating solely for his own profit through anticipating the trend of the market.

5. The *specialist,* as his title implies, is a broker who confines his operations to a single group of securities. He may act as a two-dollar broker, an odd-lot dealer, and a floor trader in his chosen field, but he is not permitted to act as both dealer and broker in any single transaction and thus secure a commission while at the same time selling a security at a profit.

New York Curb Market. In many cities, outdoor street markets have grown from small beginnings; such a one was that in 'Change Alley, London, which existed for almost a century. There are several of these curb markets, as they are called, in the United States, the greatest of which is in New York. Its origins go back to 1792, and until recently it has always actually carried on trading "on the curb"—that is, in a roped-off area in Broad Street adjacent to the Stock Exchange. Before the Curb Market moved indoors to its own building at 78 Trinity Place it was one of the major sights of the city to watch the buying and selling activities of brokers and dealers who, without any legalized organization, stood in groups in all sorts of weather and shouted out their bids. Records of transactions were sent by a complicated system of signals to operators at windows near by, who relayed these by wire to the brokers' offices and to customers.

The New York Stock Exchange brokers deal only in securities that have been examined and placed on the Exchange's list. The Curb Market handles stocks of a more speculative type, and unfortunately has been the scene of many operations in questionable enterprises. However, the brokers gradually came to perceive that such unscrupulous games, if openly permitted, would impair the confidence of the public, upon which they must depend, and rules maintained by a gentlemen's agreement among brokers were formulated. The New York Curb Market Association, organized in 1910, established a constitution and rules administered by a governing

board of fifteen members, and is otherwise similar to the senior exchange. Associate memberships are allotted to members of the Stock Exchange who also maintain Curb departments in their offices.

The Curb lists at present (1932) about 1,000 securities, the majority of which are in mining enterprises. Mining stock has for many years been the mainstay of the Boston Curb, another street market with a long history. The New York Curb Market does not deal in or quote any securities listed on the Stock Exchange, although many securities are "seasoned" on the Curb and later graduated to an Exchange listing. According to the Curb Association, its function is to provide (1) a primary market for approved speculative shares, (2) a temporary market for shares in established companies undergoing reorganization or issuing new stock represented by "rights," (3) a market for new speculative shares, and (4) a market for active stocks or bonds not listed on any other exchange. Those who would seek to abolish curb markets as iniquitous are disposed to overlook these useful functions, and also to disregard the fact that, so long as shares of stock, or pieces of paper, or any other commodity upon which people place value exist, there will be trading in these commodities. If buildings and other facilities are not available for this purpose, trading will be carried on in the streets or wherever else the public gathers. Although the New York Curb Association is now under its own roof it would not be at all surprising to see the rise, in the future, of other outdoor markets for speculative shares.

Other security markets. The United States possesses more than twenty separate stock exchanges in its leading cities. Among the most important of these are the Boston Stock Exchange and the Boston Curb, which for many years listed a preponderance of mining shares. San Francisco possesses a Stock and Bond Exchange, a Curb Exchange, and a Mining Exchange, which has had a tumultuous history but whose power has almost altogether departed. The Chicago Board of Trade is the world's greatest produce market.

Abroad there are organized security markets to supply the credit machinery demanded by modern civilization. The Paris Bourse is conservative, is subject to governmental control, and is more favorable to sound investment than to speculative trading. Only seventy members are admitted, and a large sum is bonded to the government by each member as security against losses; in the ordinary sense the Paris stockbroker does not fail. There are, however, a host of "curb" brokers. The Berlin Börse is likewise under governmental

supervision, and speculation there is frowned upon. The Amsterdam Bourse is important, and for many years it did a good business in American securities. Japan has security markets in Tokyo, Osaka, and elsewhere; while even China has organized a stock exchange at Shanghai to serve the needs of industrial development.

Functions of stock exchanges.—The stock exchange is an integral part of the modern economic structure, and performs the following primary services:

1. The stock market furnishes a means of liquefying capital by enabling it to flow freely and to be profitably distributed among various industries. Without a stock exchange, a person investing in one form of enterprise would not easily be able to convert his interest and reinvest it in another venture, and capital would become frozen.

2. The stock exchange enables the investment of money for short periods. Its facilities encourage a great deal of investment that would not otherwise occur. Any surplus capital may be put into the purchase of securities with considerable assurance that this money may be withdrawn at any time at a price reflecting the world market for these securities at the moment. Such a situation enables commercial banks and insurance companies to place the money of their customers in investments with widely distributed risks and at the same time to be able to repay deposits on short notice.

3. Price quotations are an index, to a fair degree, of the merits of different investments as reflected by world supply and demand; and a change in any of the innumerable factors affecting the value of an industrial enterprise is quickly indicated. Such stabilization of values promotes the financing of modern industry by inducing people to invest who would otherwise be at a loss to know what price should be paid for various securities.

4. One of the greatest functions of the stock exchange is to test new and unseasoned securities. New issues can be underwritten and the enterprise developed during the period of speculative activity. Lacking such sources of capital, ventures could be entered upon only with the greatest difficulty, and industry would be hampered.

The New York Stock Exchange has been the subject of innumerable attacks and caricatures. Lumped in the popular mind with the financial powers often termed "Wall Street," it has long been the bogey of radical speakers and writers, and at times has aroused profound hatred, leading to such manifestations as the attempt to dynamite the Exchange in 1920 which caused thirty deaths and injuries to more than a hundred men, women, and children. The complicated

machinery of trading has fostered suspicion in those ignorant of these methods, and the yellow press has fomented the idea that the exchange is merely a band of thieves organized to plunder society, a large-scale gambling hell in which the trusting "lamb" is fleeced of his savings. The fact that its organization does offer opportunity for people to give expression to the widespread human trait of speculating does not nullify its usefulness in performing the above-mentioned functions; nor should the activities of wolfish operators, confidence men, and shady promoters obscure the fact that most brokers carry on their business with honesty and ethical dealing.

It is true, however, that despite its many rules the stock market has been used as the scene of a hundred and one dishonest schemes, and it is still necessary for public agencies to spend large amounts of money endeavoring to protect the unwise, uninformed, and greedy investor from the consequences of his acts. No one who does not have a large fund of information and experience can hope to make a fortune in stocks, any more than he could make a fortune in any other occupation without knowing the rules of the game; and even those investors and brokers with the greatest reputations for alertness are far from infallible in their judgments. A few of the methods by which investors may be protected from themselves will be mentioned later in this chapter.

Operation of a stock exchange.—A brief description of a common market transaction will serve to show how the stock exchange operates.

Suppose a man in a city some distance from New York decides, after studying the records of past transactions and other factors which may influence future value, that he is willing to purchase some shares in a certain company. He goes to the offices of a commission broker where he is known and has an account, or where his credit is good, and there authorizes an order to purchase—either at the market price, or at a certain stated price. He also marks on the purchase order a time limit after which it will become void. The order is recorded and swiftly transmitted to the broker's New York headquarters, whence it is relayed to the broker-member of the firm on the floor of the Exchange. If the order is for less than one hundred shares it will probably be turned over to an odd-lot broker to handle; while if it is limited to a price far from the current price it will probably be turned over to a broker specializing in that particular type of security.

Assuming, however, that it is an order of a sort suitable for

handling by the commission broker himself, he would take it to the "post" about which congregate all Exchange members interested in a particular type of security, such as rails, steel, sugar, rubber, or the like. Here he would encounter another broker who, perhaps, had just received through his office an order to sell a like number of shares of the same stock, owned by an investor who had decided that the time had come when he should dispose of his holdings at the market price. Each would add his voice to the clamor of bidders about the post, and when a price was offered at which each broker considered that he could act for the best interests of his customer the exchange would be agreed upon. Each broker would make a note of the transaction and forward it to his office, while an alert attendant of the Exchange would send news of the sale by wire to the offices of the New York Quotation Company in an upper story of the building. Shortly thereafter, both buyer and seller could note, from an enigmatic set of letters and figures on the tape of the ticker in their brokers' offices, that their orders had been fulfilled. In a short time the buyer would receive formal notification from the broker, and arrangement would then be made concerning payment and delivery. The commission to cover the services of the broker would of course be deducted from the customer's account.

The acceptance of a bid at the floor-post marks the point at which an order is executed, and both brokers are bound by inviolable, though unwritten, agreement to complete the contract—even though acceptance depends on no more than a nod of the head—no matter what sum of money may be involved.

Stock exchange terms.—A number of terms are used in market transactions to describe common operations. Only a few of these can be defined here.

A "bull" is one who purchases shares in the hope that their price will rise. A "bear" is one who sells borrowed shares in the hope that the market will decline and he can then replace the shares at a lower price than that for which he sold them. This practice is known as "selling short," and the epithet "bear" is said to derive from the story of a hunter who sold a bearskin before he killed the bear. A "stag" is one who takes shares in a new issue with the hope of selling them at an advance as soon as the shares are listed on the market.

The purchase of shares on credit is termed "buying on margin," by which a purchaser supplies cash or collateral for a certain margin or percentage of the cost, and the broker lends, or undertakes to borrow, the balance, charging his client with interest. The broker

retains the certificate until the full amount is paid, but the purchaser owns the stock, is entitled to dividends, and can sell if the price rises. If the price falls below the amount covered by the margin and no additional margin is forthcoming, the broker is entitled to sell the stock to protect himself.

A "bucket shop" is the term for a fraudulent activity which government agents are rapidly making obsolete, but formerly many hundreds of thousands of dollars were taken by these fake brokers' offices. The bucket-shop keeper encourages his gullible clients to order stocks which he confidently predicts will rise in price, and pockets the margin which has been put up. There are innumerable variations upon this fraudulent theme, the most successful of which seems at present to be the installment-buying stock racket.

MARKET MANIPULATION AND PROTECTION OF INVESTORS

The losses through speculation in wildcat promotions and stock-jobbing schemes are tremendous. Andrew W. Mellon once estimated that the annual loss to the American public through fraudulent manipulations was $1,700,000,000. A large body of unscrupulous men are continually exercising their subtle talents to market manipulation schemes or confidence games of a thousand varieties, while a number of opportunities for sharp practice exist in the stock market that furnish many case-studies on the borderline of ethics.

All investment implies more or less risk, and as long as prices fluctuate there will be inducement to speculate. It seems absolutely impossible under any financial system to guarantee the investor against loss. The most that can be done is to encourage the existence of a fair and free market that will focus world opinion on the degree of desirability of particular investments. Excessive legislation restricting the flow of capital is dangerous, as Justice Holmes of the United States Supreme Court has pointed out:[1]

> But legislatures and courts generally have recognized that the natural evolutions of a complex society are to be touched only with a very cautious hand, and that such coarse attempts at a remedy for the waste incident to every social function as a simple prohibition and laws to stop its being, are harmful and vain.

The best protection that an investor can obtain is not the paternalistic guardianship bestowed upon an ignorant child, but rather an educa-

[1] Chicago Board of Trade Case, May 8, 1905.

tion in sound financial theory and a knowledge of some of the more obvious hazards to legitimate investment. A few of these hazards will here be mentioned.

Making a market for shares.—The process of introducing a new security issue may be conducted, as may most business affairs, in a straightforward and ethical way, or by unscrupulous and even fraudulent means.

The honest mine promoter sets out frankly in his prospectus the purposes and potentialities of his venture and invites support through subscription to the stock issue. If the capital is subscribed, he proceeds with the development and equipment of the property. He keeps the shareholders directly informed up to the minute concerning all pertinent happenings, by means of clear and accurately worded reports. Such events generally have sufficient news value to be promptly published in the financial or technical press; any phenomenal developments will be broadcast in the columns of the newspapers, without any need for the promoter to advertise his progress in screaming advertisements. Some men have a proper skill in dramatizing their promotions through the press, but it is easy to pass in this regard beyond the boundaries of good taste, and it is always better to avoid any flavor of exaggeration and to state the situation with strict adherence to the engineering method of assembling facts. During the progress of development work there will occur inevitable delays and disappointments; these unfavorable events should be presented to the shareholders and to the public with the same dispassionate exactitude as the later events, happy or unhappy, which attend the stage of operation and production. The crowning event will be the entry of the mine into the dividend-paying class, an event with such news value that the public will be fully informed without resort to paid publicity.

Unfortunately, many highly speculative enterprises are not promoted with such regard for ethical conduct. Among the flagrant methods of making a market for shares are two which have lined the pockets of stock manipulators in the past. These are (1) the ballyhoo type of publicity, and (2) "wash sales." Both methods may be used concurrently in the same promotion.

The greatest ally of the unscrupulous promoter is the printing-press, for by its use he can play upon the greedy hopes of many investors who, lured by artistic word-pictures depicting the possibilities of great wealth, form a willing market for new shares when they are at last placed on sale. A typical promotion of this sort was the

launching of Yukon Gold stock. Days and weeks before the certificates were printed, notices began to appear in the financial columns; for the promoter had a personality which appealed as "copy" to the yellow press. The possibilities of the unknown lands of the north; the fortunes already made there by haphazard methods, and the vast profits to be gained in huge, organized undertakings; the fabulous riches to be won in mining ventures—all these were called up to excite the imagination of the speculating public. A few days before sales were to begin the well-known and picturesque advertisements began to fill large spaces in the newspapers, full of wonderful promises and statements that within ten days after initial sale the price would double. When the day of opening sales came the brokers found a ready-made demand, and quotations were forthcoming. Orders swamped the street, and gesticulating mobs surged back and forth over the asphalt in an effort to buy before the expected rise would come. Such an artificial demand did of course create a rise, but the 3,000 speculators who had been induced to buy shares in expectation of a doubling of price soon found that the promised increase did not come to pass; it was spoiled by a group that unexpectedly threw 200,000 shares on the market. Although Yukon Gold shares fluctuated around four dollars for several years, the promotion from the investment point of view was a fiasco of the first order.

It would seem that most thoughtful people ought not to be taken in by the extravagant and florid ballyhoo of a fraudulent promotion and that the conservative statements and trained precision of the reports of responsible engineers ought to appeal to them as indicative of an honest enterprise. If it were merely a matter of dispassionate discrimination, the ballyhoo method of promotion would soon fall into disuse; but the dreams of the hopeful speculator seemingly make it impossible for him to be coldly logical. It would appear that the gambler in all of us loves to be deceived. The sucker class upon which the promoter of unworthy securities depends is not interested in facts or financial calculations; it is drawn away from precise engineering statements by the iridescent mirages so cunningly evoked by the word-artists; and through greed and credulity it is trapped by even such crude bait as the stock-selling appeals quoted in the previous chapter. Too often, the buyer of widely publicized shares has discovered to his cost that he has not made an investment but has merely purchased a few pages of flattering fiction.

Even though a promoter may succeed in having an issue listed

on the Curb, a lack of trading will prevent the publication of quotations and no one will be able to form an idea of the value of the shares. Promoters may, however, establish quotations at their own price by means of the dishonest practice of "wash sales." Through the connivance of brokers who pretend to carry through transactions and thus obtain false quotations, a fictitious flurry of activity in the market may be created. The wash sale is in reality no sale at all, since the securities do not change hands. Fictitious transactions are forbidden by the rules of the New York Stock Exchange, which provide the penalty of expulsion for members indulging in such practices. The wash sale is a comparatively crude method, and is usually replaced by a more refined technique, the "matched sale," which although it requires more trouble and is also forbidden by the rules of the Exchange, is safer and borrows respectability. By this method, the manipulator will issue orders through different brokers, one to buy and the other to sell shares at certain prices. The manipulator thereby sells his own stock to himself through the market, thus obtaining a recorded quotation advantageous to himself at no greater cost than the usual brokers' commissions. The brokers may be entirely innocent of complicity in this outlawed practice, and unaware of the part they are playing in launching an enterprise upon the public by such methods; but unfortunately some of them are not.

"Cross sales," which are sometimes confused with the dishonest practices mentioned, are also restricted. Commission brokers and specialists often find that they have orders on their books to buy and to sell the same amount of a certain stock at the same price. Before the broker can "cross" these orders in his own hands, he must publicly offer to sell the shares at one-eighth of a point higher than the order to buy which he holds. If the offer is not accepted, he is considered to have acted in the best interests of the seller and is free to cross the orders.

Short selling.—Selling goods for future delivery is a common practice in business by which credit is extended through postponing actual delivery. The short sale of securities has already been defined. The short seller, or "bear," according to financial theory serves a useful function in depressing prices of shares when they are higher than the state of the market warrants. In mining camps the short seller is looked upon as a pessimistic "knocker" and a traitor to the "booster" gospel; but so long as he confines his efforts to staking his money upon his belief that the market price is too high his activities

cannot be condemned out of hand. Most critics of short selling do not question the stabilizing value of the practice, but do claim that it can be an edged instrument for maliciously depressing values. If "pools" can be formed to hammer prices down, by one discreditable means or another, the short sale may be used to precipitate depressions and panics. Even as buying pools, or large combinations of stock operators, may cause frenzied booms, so may selling pools accelerate the decline in prices and hasten the onrush of a panic period at a violent rate. Short selling may be condemned as unethical, the profit deriving in many cases from much human misery. Many attempts have been made during the history of stock exchanges to legislate against short selling as such, but none of these regulations have remained long in effect. The subject has again come into prominence at the present time (1932) through Congressional investigation, but although it is likely that a few operators sell short with malicious intent it does not seem reasonable to ban the practice even to protect investors in times of rapid price changes.[2]

Corners.—Cornering the market for desirable securities may bring about monopoly prices. Corners in shares are of two kinds. Every promoter who starts to market the shares of a company may be said to have a corner on them, for when he begins to issue the shares his company owns them all. If he can create a demand for them by advertising he can put the price up at will to the point where demand falls off. The other and usual form of corner is that in shares which have been on the market for some time and are well distributed. It sometimes happens that traders sell short more shares than they could deliver if they had the entire number issued. In order to make delivery, they must go to the man who has the shares and buy from him, at whatever price he chooses to set, the number of shares they need to make good their deliveries.

One of the most disastrous corners in late years, in which many speculators were "caught short," was that on Northern Pacific Railway shares, when securities that had been selling at about $150 were advanced to more than $1,000 by the time delivery was to take place. The Hale and Norcross corner of January 1868 was one of the most extreme. Shares (which were in "feet" in those days) in this Comstock mine were at that time selling for $141, but a month later were quoted at $7,100 and no shares were to be had at any price. The Stock Exchange suspended the shares from the list, so that no official

[2] See Whitney, Richard, and Perkins, W. R., *Short Selling: For and Against.*

quotations were made, and the bulls and bears were left to settle their mutual troubles outside of the Exchange. Some of the "shorts" settled for $12,000 a foot. In May 1868 Hale and Norcross feet sold for $44.

Rumors and tips.—One of the most potent weapons in the armory of the wildcat promoter is the power of rumor. Newspapers have been guilty of coloring news—either favorably or unfavorably—in the interests of shady promotions. The spread of gossip from person to person is also a fruitful means of causing market fluctuations; bad news as well as good news runs like a prairie fire, and the slightest breath of suspicion may be enough to cause a run on a bank or a storm on the floor of the Stock Exchange. "Straight tips" from mysterious, benevolent-seeming acquaintances under some real or fancied obligation to the tippee have led more than one credulous speculator to financial destruction. The tip was the favorite method of the bucket-shop keeper to mislead the judgment of his dupe. It is not a widely known fact, but is none the less true, that many so-called "free investment services" and seemingly responsible periodicals devoted to financial advice are in reality organs of market manipulators who seek to impress the reader with the reliability of their advice as a prelude to booming in their pages one or another unsavory promotion scheme. Such "tipster sheets," as they are termed by those who know their real function, also add to their income by selling to shady promoters and confidence men the lists of their subscribers, who may be expected to bite on other schemes of dubious merit.

Misrepresentation of reports.—The importance of clearly written and comprehensive reports by engineers has already been noted. Annual company reports to stockholders should also present all pertinent facts clearly and impartially. However, many reports are written to conceal facts rather than to reveal them, and seek to do this by misleading statements, vague generalities, and roseate views of present and future activities. The British requirement of sworn annual reports at least permits the investor and the public to examine the status of a company and enables valuable trade statistics to be compiled. A step in this direction is made by the "blue sky" laws of various states, which require all securities to be registered under a securities commission, and by the Federal Securities Act of 1933. Some examination of the status of a company applying for listing under the rules of the Stock Exchange is also made.

It occasionally happens that unfavorable reports by engineers are suppressed by brokers and promoters when launching a security issue. If these men continue to sell shares after a first warning, the engineer is justified in making public the nature of his report; for if there is any suspicion of fraud he owes it to himself as well as to the public to make his position clear. It is not unknown for a fraudulent prospectus to quote a glowing report under the name of a prominent engineer who has never seen the property or has made the report many years before. In such a case of outright misrepresentation, the engineer usually makes use of the columns of the technical press to broadcast a denial of the alleged state of affairs. Ordinarily he would also be justified in prosecuting a suit for damages, but dislike for such litigation, or difficulty of proving amount of damage, makes such suits virtually unknown.

Selection of directors.—A great measure of protection may be given the investing public by the selection of wise directors to head companies.

The English system of directorates has many features that might well be imitated in this country. In the first place, the duties of directors are explicitly defined by law. Again, the fees paid the directors are much more liberal; instead of receiving a small sum for each meeting attended, the English director is usually allotted an annual fee of from $500 to $5,000, for which he is expected to devote more than perfunctory attention to the affairs of the stockholders. This better remuneration has led to the growth of a class of professional directors, many of whom can thus afford to become sufficiently informed in technical matters to discharge their duties with more than ordinary capability. The amateur director all too frequently gains his financial education to the detriment of the shareholders. An objectionable feature of the British system is the practice—happily not so popular as in former years, but still conspicuous—of appointing dukes, earls, lords, generals, and admirals to the directorship of companies, in an effort to inspire public confidence and to attract subscriptions to security issues. Aside from the prestige of their titles, such men often lack the necessary qualifications for an enlightened administration of company affairs.

The American director, on the other hand, has few legal responsibilities and often seeks a place on the board in order to protect the interests of himself and his friends. The "dummy" director and the type that sit on the board for what they can learn to their private trading advantage are not unknown, but there are many signs of a

higher order of trusteeship in the past few years, accompanied by a shrinkage in the ranks of the old-time directors who quarreled about being first to see the telegram from the mine in order to be first to trade upon the news in the stock market.

The duties of a director are to carry out his legal obligations in letter and spirit; to attempt to represent the interests of all shareholders, great and small; to conduct the business upon sound economic policy; to have no interests that may in any way clash with his company duties; and to inform himself on all phases of the company's activities. If a mining director, for example, can pay a few visits to the mines, he will learn in a few days a number of facts that will better enable him to carry out his trust.

Directorates of American companies are often large: one New York bank has eighty-two on its board. A fairly large group will of course permit a greater number of interests to be represented; but such an unwieldy membership would make it impossible to transact business were power not vested in an executive committee. There is usually one dominating personality on every board who will in general guide the policies of the company, and care should be taken that such a leader is not of the type who will rule for his own selfish gain or foolishly drag the business to the brink of ruin.

A wise tendency in recent years is to appoint the general manager of the mine to a directorship; since it is in his hands to make success or failure of the company's properties, he should be close to the fountainhead of company policy. A further extension of this idea is to make consulting engineers directors, and to appoint a number of independent engineers to the directorate to form an advisory committee upon technical problems of administration.

Much outcry has been raised against multiple directorships. Although there is no logical reason why a man should not serve on several boards, as long as he is not slighting his duties to any one of them, it is obvious that no one can faithfully function as director in twenty or thirty companies of varied aims without danger to the interests of the stockholders he is supposed to represent. But, as has already been said, the stockholders are ordinarily scattered and inarticulate, and even if directors are incompetent or worse, it is extremely difficult to oust them from their seats.

Summary.—Much has been said and written concerning the protection of the investor, and many endeavors have been made to assure a fair and open market for investment in shares. The duties of promoter, broker, director, engineer, and government agencies in

this regard have here been touched upon, and the "blue sky" laws of the states and other curbs on the dishonest promoter have been discussed in the previous chapter. In the last analysis, however, the investor himself must find the remedy for existing abuses and make his influence felt to insure its application. The chief remedy is education. The investor cannot afford to add to the risk of legitimate speculation in shares by ignoring the vast body of information regarding the buying and selling of shares that has been accumulated in the past. He should not plunge into any scheme without first making sure that he has thoroughly studied and analyzed all available facts and investigated the reputations of all those with whom he is to deal. It is only in this way that he may hope to guard his savings from being lost in the toll annually exacted by wild promotions and cunning stock manipulations.

THE ENGINEER AS INVESTOR

Almost four hundred years ago, Agricola wrote a paragraph of advice to buyers of mining shares that holds good for investors in this year of grace:

> Some owners prefer to buy shares in mines abounding in metals, rather than to be troubled themselves to search for the veins; these men employ an easier and less uncertain method of increasing their property. Although their hopes in the shares of one or another mine may be frustrated, the buyers of shares should not abandon the rest of the mines, for all the money expended will be recovered with interest from some other mine. They should not buy only high priced shares in those mines producing metals, nor should they buy too many in neighboring mines where metal has not yet been found, lest, should fortune not respond, they may be exhausted by their losses and have nothing with which they may meet their expenses or buy other shares which may replace their losses. This calamity overtakes those who wish to grow suddenly rich from mines, and instead, they become very much poorer than before. So then, in the buying of shares, as in other matters, there should be a certain limit of expenditure which miners should set themselves, lest blinded by the desire for excessive wealth, they throw all their money away. Moreover, a prudent owner, before he buys shares, ought to go to the mine and carefully examine the nature of the vein, for it is very important that he should be on his guard lest fraudulent sellers of shares should deceive him. Investors in shares may perhaps become less wealthy, but they are more certain of some gain than those who mine for metals at their own expense, as they are more cautious in trusting to fortune. Neither ought miners to be altogether distrustful of fortune, as we see some are, who as soon as the shares of any mine begin to go up in value, sell them, on which account they seldom obtain even moderate wealth.[3]

[3] *De Re Metallica*, pp. 29–30.

From a study of the results of speculation in shares of mines throughout the world during a long period, the following rules have been evolved as an aid to young engineers who wish to invest in such shares.

1. Never buy a share in a mine that you have examined without having first reported to your client.

2. Never buy a share in a mining company solely on the advice of someone else. Investigate all available data before resolving to purchase.

3. Never under any circumstances buy stock on margin. Having made up your mind to purchase, go to a broker and buy outright the number of shares that you can afford to pay for at the time, and deposit the certificates in your safe. You will then be protected from sudden demands which by a mischance may make at any time heavy calls upon your cash and credit.

4. Never buy a share of stock in the hope of a quick rise. Buy rather for the long swing of the pendulum, in such times as those when the industrial stocks of minerals or mineral products are low, or during the early stages in the development of a mine.

5. Never sell a share of stock that you do not own.

6. Before buying, consult your broker and at least three firms of investment bankers.

7. Buy no share in a property that does not pay an income, or that may not conservatively be expected to pay an income soon.

8. Never buy shares on which dividends are guaranteed. Legitimate mining is too perilous a business to be able to pay assured dividends of a specified amount, and such guaranties are frequently the bait of a dishonest promotion.

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Chapter 16

Fluctuation in Price of Shares

The market prices of shares on the stock exchange are in a state of continual fluctuation. Such fluctuation is a result of the working of a number of factors, and frequently the market price is at great variance with the true value of the stock, i.e., the value that would be placed upon the given property through application of the principles of valuation laid down in Part One. Among the major causes of fluctuation in prices of mining shares are (1) the incidence of the prosperity-depression cycle of general business conditions, and (2) the rise and fall of values reflecting a similar cycle within the mining industry itself. Acute variations in these cycles occur when conditions lead to the excessive optimism of boom times and to the collapse of confidence which may follow and result in frightened selling and financial panic.

To list some of the factors causing fluctuation in mining-share values, to describe briefly the typical course of the business cycle and the boom-panic phases of the mining industry, and to define the position of the engineer with reference to fluctuations in the value of shares are the aims of the present chapter.

FACTORS CAUSING FLUCTUATION IN MINING-SHARE VALUES

The factors causing fluctuation in market prices of mining shares may be divided into those that represent a change in the true value of the property and those that represent a change in market price independent of true value.

Factors representing change in true value.—A change in the true value of a mining property is frequently, but not always, reflected in a corresponding change in market price of the shares. If such changes are known to the investing public and properly evaluated by them, it would be reasonable to suppose that the market price of the shares would approximately reflect these changes; but this is not always the case.

The more important factors that may cause a change in the true value of a mining property may be outlined as follows:

A. Factors extraneous to the property:

1. *Changes in cost of production.* A number of factors influencing cost of production of metals have been given in chapter 7, pages 133–46.

2. *Changes in selling-prices of metals.* The main causes of fluctuation in the selling-prices of mineral products have been given in chapter 10, pages 184–93.

3. *Changes affecting all industries.* Major changes in social, political, and financial conditions may influence the true value of any industrial property. Wars and revolutions may either cripple or spur production. Changes in political policies or the passage of new legislation may alter the business outlook. Inflation or deflation of currency may cause a variation in the comparative values of all commodities, including the products of mines.

B. Factors inherent in the property:

1. *Change in management.* Although some mines would make a profit under almost any sort of management, and others would be failures no matter how skilfully managed, a third and large class of mines comprises those that will succeed or fail in proportion to the ability of the men controlling operations. The valuing engineer can foresee the effect that management will have upon the true value of the property, but he cannot be sure that the property will always have sound management; and if subsequent development is placed in the hands of incompetent managers, the venture may be wrecked and the true value may shrink to nothing, or the mine may even become a liability.

2. *Change in the ore with depth* is perhaps the most common cause of variation in the true value of a mining property. Developments unforeseen by the valuing engineer may reveal failure of continuity, or may on the contrary open up rich reserves. An oxidized ore may give place to a sulphide ore at lower levels and thus necessitate a complete alteration in metallurgical equipment. The vein may pinch out or diminish in value; it may even be cut off by a fault without leaving any clue to continuation.

3. *Disasters* such as fires, cave-ins, earthquakes, and floods may wreck the mine or destroy the equipment, thus materially reducing the value of the property.

4. *Lawsuits* may arise which cause a heavy drain on the resources of the company and may even result in depriving the oper-

ators of all right to a deposit which they had once considered they possessed.

5. *Reorganization* and re-allotment of rights to certain shares by action of shareholders or board of directors may make a change in the true value of the shares, although this would not affect the true value of the mine itself.

Factors causing change in market price independent of true value.—The causes of fluctuation in market price of mining shares that do not represent change in true value may be classified as follows: (*a*) making a market for shares; (*b*) activities of pools to manipulate prices; (*c*) corners; (*d*) rumors, tips, and "ballyhoo" publicity; (*e*) misrepresentation in reports.

All these methods of influencing market price have been described in the previous chapter. There are a few other factors which also may cause fluctuation in the prices of shares.

f) Fraudulent management:

Dishonest operations by officials of the mining company may be attempted in order to misrepresent the production record of the mine and thus cause fluctuations in the stock market.

This may be effected in one way by working out the richer portions of the mine for the purpose of declaring a few glittering dividends and thus enhancing the apparent value of the shares. This operation may leave the mine in such condition that the lower grade of ore cannot be worked at a profit.

Another scandalous practice is that of holding what are known as "secret reserves." This was indulged in by the managers of certain Australian gold mines some years ago. The manager, without the knowledge of the directors and the shareholders, withdrew and kept on hand a surplus of gold bullion, with the ostensible purpose of regularizing production and preventing the violent fluctuation in shares that would normally occur when the fortunes of mining uncovered streaks of greater or less promise. As a matter of fact the news of decrease or increase in the value of the ore leaked out sooner or later and was responsible for abnormal fluctuations in shares owing to absurd ideas as to the magnitude of the reserve, tending to put the price up, and for loss of confidence in the integrity of the management, tending to put the price down. Moreover, the existence of these secret reserves offered almost unlimited opportunities for fraud. It was possible to show record production by adding the reserves to the monthly shipment when the best ore was being worked, and thus cause boom prices at which the insiders

could unload their shares; then production would drop, reports would be dismal, and the insiders could recover their shares at low prices and hold them for the next coup. This scheme came to be known as "milking the market." It is unnecessary to point out that the practice of holding secret reserves for the purpose of affecting share prices is dishonest and in some countries illegal. The only honest way to manage a mine is to keep the directors and shareholders fully informed at all times of the actual progress of production and development work, and all discoveries, good and bad.

g) General business and stock exchange conditions:

In prosperous times most industrial shares will be overvalued, while in times of business depression they will sometimes be offered at prices much lower than their true values. The effect of the general business cycle upon share prices will be mentioned in the following section.

h) Mining booms:

The factor likely to cause the greatest disparity between the true value and the market price of mining shares is the outbreak of a boom, which sends the market price of certain mines skyrocketing to absurd heights before the inevitable collapse. The psychology of such booms and a description of some typical orgies of speculation will be given later in this chapter.

THE BUSINESS CYCLE

When the ebb and flow of general business activity is charted, the resulting curve reveals two different cycles representing the volume of trade in the past. Of these, the minor cycle is that which shows seasonal variation in activity, which is indicated by the changing demand for funds in the money markets from month to month. The major cycle, which rises or falls through the years, may be termed the prosperity-depression curve, and this cycle has an effect upon the market prices of metals and of mining shares.

Stages of the business cycle.—It has been said that the only normal state of business conditions is a state of change. To put it more strongly, the business of the nation is always either embarking on a spree or recovering from its effects. This phenomenon has been studied and described by a number of writers.[1] These writers point out that there are certain forces at work in the complex modern

[1] One of the most comprehensive books on the subject is *Business Cycles, the Problem and Its Setting*, by Wesley C. Mitchell.

financial structure that produce a rhythmic flow of business activity through the stages of successive prosperity and depression.

Starting at a period following a depression, when prices are low and a cautious financial policy is in order, a slow expansion in trade becomes noticeable and a partial revival in some fields of industry leads to a demand for supplies, capital, and labor. This in turn spreads throughout the fabric of commerce, produces a more optimistic attitude, and the threat of rising prices brings an abundance of orders. The rise in wages and prices spreads rapidly, profits increase, and, as the revival becomes a period of prosperity, heavy investments are encouraged and speculation begins.

The growth of prosperity sooner or later approaches the day when increase in the volume of business can no longer progress at the same rate. Certain tensions and stresses within the system make themselves felt: costs of production increase beyond the economic optimum, the demand for capital and credit becomes tense, and profits diminish under competition. The more interlocked the dependence among all phases of business, the more severe become these threatening conditions. Fear of shrinking returns causes capitalists to liquidate; this liquidating process spreads from creditors to debtors, who in turn put pressure upon their own debtors. Contraction replaces expansion; a feeling of doubt pervades the financial air; and prosperity has merged into a crisis. If the credit structure is unable to bear rapid liquidation, the crisis may develop into a panic; business is disorganized, there are fights to maintain solvency, and a greater or less number of failures in business, occurring as a result of forced liquidation, foster the growing fear. There may be bank runs, appeals to the government, and sudden slumps in share prices. The depression spreads in widening circles throughout the whole business world; money is tight, demand falls off, factories are closed and workmen are turned off, prices fall, and the depression runs its course until the wheel comes full circle and signs of awakening activity again appear.

Periodicity of crises.—The acute crises known as panics form the most spectacular stage of the cycle, since they are attended by wholesale suffering, unchecked plunges in value, and complete breakdown of credit. For these reasons panics early attracted much attention and study by economists. In the United States, the first panic of importance occurred in 1814 as a direct result of the capture of Washington by the British. The first real crisis came in 1819, and it was followed by major or minor crises in the years 1825, 1837,

1848, 1857–59, 1869, 1873–78, 1884–86, 1890, 1893–96, 1903, 1907, 1914, 1920, and 1929–33. It will be noted that the maximal interval between these periods is eleven, and the minimal three years; the average is about six years. The periodicity of panics early led to studies which endeavored to account for their more or less regular occurrence. One of the most famous of these studies is that of W. S. Jevons, who reasoned that there was some connection between the periodicity of market disorders and the periodicity of sun-spots, which phenomena presumably have an effect upon weather and crops. Another theory was put forward by J. S. Mill:

> Mill's theory is that, after the reverses in business caused by a crisis have warned commercial communities of the dangers arising from extravagance and unsound business methods, it requires a comparatively definite period for the losses to be made good, and the memory of their harmfulness to be modified. Mill held that the changes in mental attitudes of commercial communities toward business conditions and credit methods that occur in the interval between a crisis and the following boom period require a comparatively definite interval of time for their accomplishment. It is a psychological phenomenon and can be measured by psychological methods.[2]

It is likely that both of these theories contain some elements of truth, but obviously there can be no simple means of accurately measuring all the causes determining market conditions, which are a complex of a vast number of intricate forces operating in the highly developed financial system that forms the framework of modern civilization.

The business cycle and speculation.—In times of prosperity many people possess surplus capital and most of them are sure to give rein to the universal trait of gambling. Some patronize lotteries or games of chance; others buy shares of various kinds which can be had cheaply and which are reputed to be advancing to high price levels. Such a spirit arising in large masses of people produces an immense aggregate volume of buying which may cause demand to exceed the supply of shares on the market. Mass action of this sort is responsible for a boom in shares. So long as the price is thought to be rising and a buyer can sell his shares in a few days at a profit, there is no limit to the market value of stock, the true value of which may be zero. When a gleam of reason penetrates the optimistic fog in which the speculator loses himself, confidence is shaken, the bubble bursts, and a period of frenzied selling causes a panic. During the ensuing depression money is scarce and cannot be devoted

[2] Selwyn-Brown, Arthur, *Stocks and the Stock Market*, p. 157.

to gambling; the supply of shares exceeds the demand, and stock prices may fall much below the true value.

The volume of business conducted on the curb market may be taken as a rough index of the prosperity of the country. In the days of prosperity, almost any venture with the least promise of success can attract capital to itself; while during a depression so many sound securities must go begging that the highly speculative share is out of favor, and the curb sales shrink to a mere trickle.

Famous speculation schemes.—The heights of madness to which the frenzy of speculation may lead whole nations may be indicated by a short account of several of the extraordinary schemes that were promoted in the seventeenth and eighteenth centuries.[8] Widespread speculation and stockjobbery came in with the growth of early trading companies mentioned in chapter 12, and many of the projects had no real assets or logical programs whatever. One frank adventurer even advertised shares to half a million pounds in "a company for carrying on an undertaking of great advantage, but nobody to know what it is." He offered a profit of 100 per cent yearly, and 1,500 shares at £100 were subscribed, a £2 deposit being required. The undertaking was of great advantage to the promoter at least; he took the £3,000 deposited and was never heard of again.

Tulipomania. Certainly no more curious example of the workings of those obscure psychological forces that lead whole nations to idiotic and inexplicable action can be cited than the tulip craze that beset Holland in the few years before 1636. These flowers, grown from bulbs sent from Constantinople, became highly fashionable, and as the rage increased, fabulous prices were paid for a single bulb of a rare variety. A Haarlem merchant was known to have paid half his considerable fortune for a certain bulb which he wished to add to his collection. The ordinary industries of the country were neglected, and everyone embarked in the tulip trade. Tulip exchanges were formed in the larger cities, and speculation ran riot among the people, from noble to chimney sweep. Finally, a few reflecting persons recognized that the boom could not last; confidence was destroyed, and everyone became anxious to sell. Losses were great, and at last the courts refused to decide lawsuits over tulip contracts. The commerce of the country received a severe shock, from which it took many years to recover.

The tulip mania ran its course in a year or so and seems to have

[8] For a full account see Mackay, Charles, *Memoirs of Extraordinary Popular Delusions,* 1850.

had less excuse for its madness than any other speculative market of which there is record. Any reasonable person should have seen at once that the excessive prices paid for tulips must cause an enormous production of that easily grown bulb; yet the Dutch nation, certainly among the most enterprising and intelligent in the world, lost its head over the chance of making great profits in a short time.

The Mississippi Bubble. The wildest speculation ever recorded was that of the Mississippi Scheme, which set Paris in an uproar during the years 1716 to 1720 and has a mining flavor. At that time the Duke of Orleans was Regent. The finances of the country were in great disorder, the currency was debased, and the debt owed by France was unpayable. John Law, a Scottish financier long resident in the country and a favorite of the Regent, proposed to rescue the nation's credit by establishing a bank that should issue stable notes payable in coin at sight. Within a year, the Law notes were at a premium of 15 per cent, since the coinage was being continually debased by the government.

The Regent conceived the idea that paper notes might be issued in unlimited amounts without metallic backing, and it was this false presumption, later carried into effect, that caused the catastrophe. Meanwhile Law had obtained several monopolies, the largest of which—exclusive right to trade in lands adjacent to the Mississippi, Missouri, and Ohio rivers—gave its name to the scheme that he sponsored. An interesting mining aspect is given by the fact that this included the right to work the lead mines near St. Joseph, which were then known and which are still producing. Law was also given a monopoly on the sale of tobacco, the sole right to refine precious metals, and exclusive rights to trade in the East Indies, China, and the South Seas. The venture was capitalized at 50,000 shares, and an increment of 120 per cent yearly was promised.

Public enthusiasm fed on these visions of wealth, and at least 300,000 applications were made for the shares. Impatient speculators besieged Law's door and titled gentlemen begged for opportunity to subscribe. Finally the demand become so great that 300,000 new shares were issued at 5,000 livres each, in order that the Regency might pay off the national debt. Thrice the needed sum could easily have been raised. For a time trade flourished, and the population of Paris is said to have been increased by more than 300,000 people who poured into the city from all sides. Wages and prices rose, many new houses were built, and the populace was dazzled by an illusory prosperity as the Mississippi shares rose in

price, sometimes as much as 20 per cent in an hour. But the storm was approaching. The Prince de Conti, angry at having been refused the right to subscribe to some new shares, sent notes for collection in such vast amount that it required three wagons to transport the coin in which they were paid. Others, scenting trouble, began cashing their paper notes. Coin soon disappeared from circulation, and the price of the shares, in spite of the efforts of the promoters, fell rapidly. In October 1720 the monopolies granted to Law were taken away and the notes of his bank declared of no value. The Mississippi Bubble was exploded, and the realm paid dearly, in ruin and misery, for its wild orgy of speculation.

The South Sea Scheme. The South Sea Scheme was founded by the Earl of Oxford, and this English project had even less grounds for actual gainful trade than did the Mississippi Scheme. The most visionary ideas were circulated concerning the immense profits to be made by trading and mining on the coast of South America, although it was later discovered that the company had the right to send only one small ship a year to those lands. The South Sea Company also had the privilege of supplying slaves to the colonies, and was concerned with refunding the British debt. Learning of Law's success in Paris, the directors imitated his operations; and a few months before the bursting of the bubble the shares had climbed from £1 to £1,200. This scheme also collapsed in 1720, and the ruin caused was likewise enormous. During the days of its apparent success hundreds of other visionary companies were formed and the whole population indulged in fierce stock-gambling.

The psychology of booms and panics.—Many other speculative schemes might be cited to show upon what flimsy foundations people will venture their money. One project still recent enough to be painful to many Americans is the Florida land-boom. In all such episodes, shares or property are acquired not for long-term investment but in the hope that the market price will shortly rise and the buyer will be able to dispose of his holdings at great advances in price. Collapse comes when a few reasonable beings stop to consider the true value of the scheme and confidence in the roseate prospects drawn by the promoters is shaken. Even those who perceive that share prices are too high may lose money in a panic because the market is clogged with orders and they cannot sell out quickly enough to evade the consequences of a slump.

Booms and panics are manifestations of crowd psychology. It is well known that in times of excitement crowds are devoid of reason-

ing power and tend to act upon the spur of the moment; the slightest wave of impulse or leadership of any kind is likely to precipitate sudden action. Research has failed to discover any extended and serious study of the psychology of booms and panics, but the following comment by Münsterberg upon crowd action may be revealing:

> It is well known that every member of a crowd stands intellectually and morally on a lower level than he would stand if left to his spontaneous impulses and his own reflections. The crowd may fall into a panic and rush blindly in any direction into which anyone may have happened to start and no one thinks about it, or it may go into exaltation and exuberantly do what no one alone would dare to risk. This mass consciousness is also surely a form of increased suggestibility. The individual feels his own responsibility reduced because he relies instinctively on the judgment of his neighbors, and with this decreased responsibility the energy for resistance to dangerous propositions disappears. Men buy their stocks because others are doing it.[4]

Hundreds of capable men have engaged in attempts to fathom the causes of the boom-panic cycle, but it is unlikely that any panacea can be devised to prevent or greatly curb the incidence of wide fluctuations in the cycle of business. It is a complex of many imponderable factors, chief among which is fear of the future. A sound credit system to protect private property, honestly gained, is, however, the first step to be made in checking the economic loss and human suffering attendant upon a collapse of trade. Again, most of the social problems of the modern world are in essence economic rather than political, and if their solution were taken out of the hands of party legislators and given over to a body of economic counselors of high attainments there is reason to believe that greater progress in preventing economic crises would be made. Sound planning by such a national group, even if given advisory powers only, would do much to allay the fears which are too often aggravated by the tinkering politician.

Government control.—It is natural to ask the government to do something to prevent these recurrent periods of economic distress, but there is little hope that booms and depressions can be wholly prevented. They can, however, be controlled, and the chief problem before the American people is to make democracy work by gradually and wisely taking such measures as will impede the violence of these acute periods. Much has already been done and more will be accomplished. Some of the measures taken in times of distress were futile, but in the main they did help to abate the situation.

[4] Münsterberg, Hugo, *Psychology and Social Sanity*, p. 184.

MINING BOOMS

Mining booms are attended by all the phenomena of any other speculative fever, and have attained high pitch. A mining boom is a sudden tempest within the industry itself, attendant upon a strike in a particular district or upon the popularity of the shares of a certain company. Such a boom does not always coincide with the general business cycle—even during a depression there seem to be funds to stake a rush to a newly discovered bonanza—but it may be said that in prosperous times there is more money available for investment in mining, as for investment in other industries, and any discovery or promotion will attract a great volume of speculative capital.

The usual course of mining booms may be best understood by describing several of the most noteworthy of latter years and their effect upon the market for shares. There seems to have been but little dealing in shares in the days of 'forty-nine. In those times men speculated by working mines rather than by trading in shares; they were in fact one-man mines carried on with little capital and co-operation. It was not until the development of the Comstock in 1860 that any extensive mining-share speculation arose. Since the decline of the Comstock the chief speculative markets have been connected with the discovery of mines in the Transvaal, Cripple Creek, New Zealand, the Klondike, British Columbia, Rhodesia, West Australia, West Africa, Egypt, Buenos Aires, Siberia, southern Nevada, and Cobalt. In an article on "The Psychology of Mining Booms," J. H. Curle said:

> These thirteen mining booms, following upon discoveries of more or less value, took without exception one definite course. After an initial period of scepticism results from one or two mines in the new district led to great financial excitement, and to wide advertisement. Outside promoters entered the field, and capital poured in; for one good mine twenty worthless ventures were floated; the shares, good and bad, rose to absurd prices; and the *facts* became obscured in an atmosphere of lying and brainless optimism. Then, sooner or later, came the crash. This was always thorough, and in each case dragged down thousands of more or less foolish and deluded people.[5]

Although it is true, as Claude Sachs[6] notes in commenting upon Curle's opinions, that in most of these booms more productive and more profitable mines were discovered after the original strike was made, it nevertheless remains a fact that the average mining share

[5] *Min. Sci. Press,* Jan. 4, 1908, pp. 8–9.

[6] *Ibid.,* Feb. 1, 1908, pp. 156–58.

during a boom is grossly overvalued on the market. Although most mining booms are based on the discovery of rich bodies of ore which add to the world's metal supply, and therefore cannot be classed with the tulip mania as mere speculative madness, the market prices of shares in almost all mines in the boom camp indicate a value much in excess of that which would be placed upon them by a careful engineering analysis.

Comstock Lode.—The greatest mining speculation of all time was that in shares in mines on the famous Comstock Lode of Nevada, which excitement led to the formation of the San Francisco Stock Exchange on September 11, 1862. The trading is described thus:

> Without and within doors, a fever of speculation raged without check. Sales of claims for money were comparatively rare, but barters were incessant. "Feet" in a thousand locations on cropping rocks or bare ground were bought and sold indiscriminately. The position or existence even of most of these so-called ledges was scarcely known, but this made little difference, for all claims had a nominal, if fictitious, value and were serviceable for purposes of exchange. Paper fortunes were made in days by shrewd sales or rumors of "rich strikes" and "assays." Pockets and hands were filled with bits of quartz or country rock and samples were brandished in the faces of friends and strangers wherever met. Eyes were strained to detect invisible specks of metal; pyrite was boastingly pointed out as gold, and pieces of worthless galena were gravely presented as black sulphurets of silver.[7]

Variations in share prices were great.[8] For example, shares in a mine called the American sold for some months at about $20 but in one day dropped to fifty cents. A rumor that a fire had been kindled in the Crown Point mine for the purpose of depressing the quotation produced a panic among the stockholders and the shares fell from $1,825 to $175 within a month. Shares in the Savage fell from $725 to $175 in a few days. Other rapid falls were common.

Equally rapid advance in share values was common. In the spring of 1872 the Crown Point bonanza came into production and the stock jumped from a few dollars to more than $1,800 a share. The same orebody extending into the Belcher raised that stock within three months from $6.50 to more than $1,500. In the autumn of 1874 the Consolidated Virginia stock jumped $100 a day for five days. The production of this mine and the adjoining California mine

[7] Lord, Eliot, "Comstock Mining and Miners," *Monographs of the U.S. Geol. Survey,* Vol. 4 (1883), p. 73.

[8] See King, J. L., *History of the San Francisco Stock Exchange Board,* and Slosson, H. L., "Early Day San Francisco Stock Market Fluctuations on the Mines of the Comstock Lode, Nevada," *Min. & Met.,* Feb. 1930, pp. 110–11.

for the years 1873–1878 amounted to more than $100,000,000. The shares advanced in proportion. One man bought 100 shares for $800 and subsequently sold them for $680,000; had he held these shares until 1875 he would have realized $1,280,000.

All imaginable methods were used to advance or depress share quotations, one method being to keep the miners underground when a drift was approaching an orebody. In 1868 the superintendent of the Hale and Norcross confined twenty-five miners for three days while piercing the clay selvage on the 930-foot level. The men were paid $12 a day and were willing prisoners. On their release it was reported that some rich ore had been found. The stock of the mine, quoted at $1,300 a foot, rose at once to $2,200. But this trick was worked too often, and when it was known that miners were imprisoned the shares ordinarily fell.

Trading on the San Francisco Exchange was brisk; the commissions of one broker averaged $50,000 a month for a long period. The recklessness of speculation of the Comstock days can be judged from the statement of the cashier of the Pacific Bank that one day his bank received $25,000 in coin without a deposit slip and the money was never claimed by anyone.

The Comstock speculation was the greatest in mining history, for in no case has a mining company brought in such fabulous production as that of the "big bonanza" in so short a time. The Comstock is the lucky exception that proves the rule. As Slosson says:

> There is much to be said for this system of mine development in a district where mining must of necessity be highly speculative. The public over and over again paid assessments and carried on speculation where the millionaire, advised by a cautious engineer, would have stopped long before. The Consolidated Virginia, which was a barren piece of ground down to the 1100-foot level, and which yielded the world's greatest orebody below that level, is a case that illustrates how this system is sometimes rewarded.

The Transvaal.—The Witwatersrand deposits were located in 1885, and part of the district was proclaimed public diggings in the following year. The hitherto empty veld became the scene of the usual stampede, but primitive methods soon gave way to more extensive—and expensive—methods when it was recognized that the proper working of the "banket" deposits required strong organization and the expenditure of large amounts of capital. The rapid increase in production caused a heavy upward sweep in share prices, culminating in the boom of 1888–89 and followed by the usual slump. Although the steady output soon restored confidence, there was a common

belief, which died a slow death, that the sedimentary origin of the reefs guaranteed the permanence and uniformity of the ore shoots. Shares in many of the mines of the Rand were ridiculously overvalued for many years, as will be discussed in chapter 17.

West Australia.—Sporadic gold strikes of little importance were made in Western Australia from 1885 on, but the boom did not begin until 1892 with the location of the Coolgardie fields and the Kalgoorlie district the following year. Although a few small tracts, such as the famous "Golden Mile" at Kalgoorlie, were extremely rich, the gold seeker who penetrated this desert land was almost always disappointed, for there were almost no alluvial deposits in the region and the reaction from the boom revealed that there were less than a dozen good mines in the Kalgoorlie field. The usual boom hysteria accompanied the early stages of the West Australia operations, and although shareholders in a few mines made large profits the output of these fields began to decline in 1903. Of the Westralian boom Edward Hooper said:

> When I first came to this field, the boom was commencing and everybody was in a feverish state of excitement. This led, of course, to the upspringing of that most dangerous pest on every new gold field, the bogus mining expert. They came in swarms, followed by the unscrupulous company-monger, with whom they formed an unholy alliance that came near wrecking these fields at the outset. I have seen a good many mining camps in the course of my travels, but never struck one where unblushing ignorance and impudent imposture were so rampant.[9]

Southern Nevada.—The liveliest mining-share market in recent years was that in the mines of southern Nevada, where great profits were made by the Tonopah and Goldfield properties. This boom started in 1900 and lasted until 1907. It was initiated by the discovery of a prospector, who while searching for his wandering burro stumbled upon the outcrop of a rich silver ledge on Mount Oddie and there staked out the Mizpah claim. Men flocked to Tonopah, formed wildcat companies, raised large amounts of capital for prospecting and development, sent out hundreds of prospectors, and sank shafts in all hopeful and many hopeless places. The original Tonopah mine was also the richest, although shafts driven through hundreds of feet of barren rock near this property developed other paying mines. This activity increased the excitement of the boom, and when the neighboring mines of Goldfield were found speculation was at its height. The activities of scoundrelly promoters

[9] Interview in *Australian Mail,* Feb. 10, 1898.

stimulated gambling, and hundreds of millions of shares in worthless Nevada claims were put into circulation. Variations in share quotations were preposterous; a share might jump 50 per cent in the morning and decline 60 per cent in the afternoon. The southern Nevada boom culminated in 1906 when speculation was checked by the San Francisco earthquake and the subsequent panic of 1907.

SHARE FLUCTUATIONS AND THE MINING ENGINEER

The mining engineer who makes a valuation of shares according to the method to be discussed in the next chapter must come to the conclusion that almost all mining shares, judged by market price, are overvalued. What, then, should be the position of the engineer with regard to investing in, and advising others to invest in, mining shares the value of which is more or less speculative?

The mining engineer as speculator.—There is an idea in the minds of some people that if anyone is likely to make money by dealing in mining shares the mining engineer should be that person; but it is nevertheless true that engineers do not often make large profits through such speculation. In fact the engineer seems to be in but little, if any, better position than the general public in gauging the rise and fall in share prices. He is inclined to buy on merit, and it is not always merit that governs market price. The market operator whose chief business is speculation is in a much better position than the engineer to comprehend what will be the effect of discoveries or reverses in the development of a property, and he acts instantly, while the engineer is still pondering upon the influence that the new factor will exert.

Those engineers who make fortunes from mines, aside from saving their fees and salaries, do so ordinarily by acquiring interests in meritorious mining businesses in their early stages and retaining their shares until high dividends are paid or the shares have climbed to a price at which the holders are willing to sell. This price at which the engineer is willing to sell is, of course, somewhere near the true value of the property. If he holds on for a higher price than this he becomes a speculator and as such is aiming to unload his shares on an unwitting or gullible public at a price in excess of the true value. Even if he is independent and honest, it is highly unethical for him to profit in any way by the ignorance and cupidity of the public. The engineer need not try to soothe his conscience by reflecting that mines are uncertain and that the public may be better

able to guess the true value than he is. Although it is true that many times the price at which the engineer is fully justified in selling will be doubtful, if he is certain that he is taking an advantage of the public he should not unload his shares without taking very definite precautions to protect himself from criticism. These precautions serve alike for the honest engineer or promoter or director who owns shares in a business to which he is attached in an official capacity; and this important ethical point deserves extended consideration.

Selling shares at boom prices.—It should first be noted that there are two classes of shareholders who may be concerned with a mining enterprise. The first of these is the group that has initially subscribed to the shares, has paid the face or par value of those shares into the company treasury, and may therefore expect to realize the hopes set forth in the prospectus that induced its support. The second group is composed of those buyers who, during a rising market, will gamble by trading in the company's shares in the hope that they may shortly sell at a great advance in price. Assuming, of course, that the promoter, engineer, and company officials are honest and that they have had no part in creating the boom prices at which shares are currently offered, is there any difference in the loyalties and responsibilities that they hold toward the two groups?

There is a great difference in their relationships toward the original subscribers to the enterprise and toward those who have later, at a time when a boom may have jumped the shares to tens or hundreds of times their par value, purchased these shares from original subscribers with the intention of gambling for a rise. If neither the promoter nor the original subscriber has had a hand in causing the increase in price beyond its true value, neither is morally obligated to guarantee that the boom buyer will not suffer loss when the inevitable crash comes. The foolishness of speculation in booms has been set out in thousands of warnings, and the boom buyer knowingly gambles in futures which have no relation to the true value of the shares.

Consider now the most perplexing ethical case under this heading, that in which a promoter-engineer has received shares at the inception of the company, in return for money invested or services rendered, and at the top of the boom has sold these shares in the market for many times their real value.[10] Is the promoter-engineer culpable if he sells out at such a time?

[10] See Hoover, H. C., "The Economics of a Boom," *Mining Mag.*, May 1912, pp. 370–73.

There is nothing whatever censurable in the sale of shares owned by the engineer-promoter at the height of a boom if he has taken the precaution, which all of these men take and must take, of making an announcement during the boom that the shares are in his opinion grossly overvalued on the market. Such an announcement, advertised by the promoter or engineer as widely as lies in his power, ought to have the effect of bringing the market price down with a crash, but such is the psychology of these mob movements that little impression is ordinarily made by such an announcement upon the tide of speculation. Having made a clear-cut statement of his valuation of the shares and having pointed out the idiotic elements of the boom, the promoter-engineer need waste little time in unloading his shares. He need not fear that those who purchase them during the boom will be "widows and orphans cheated of their inheritances"; on the contrary, they will be gamblers who seek to pass on their purchases at a goodly profit, and if they do not, as they hope, get the better of the bargain, little pity need be wasted on their plight. As has been well said elsewhere: "From an economic point of view, this capital in the hands of the insiders is often invested to more reproductive purpose than if it had remained in the hands of the idiots who parted with it."

Responsibility of engineer for loss in value.—If a sudden drop in the price of shares takes place it is natural for human beings to seek a scapegoat, and the engineer is many times chosen to bear the blame of a loss. He should therefore protect himself as much as possible by pointing out to his clients the various factors that may cause changes in the value of properties and the price of shares. Many of these factors affecting price of shares it is impossible to foresee, but the engineer should be able to indicate what may happen and the possible influence of such events. He can point out, for example, that the probable price of the metal product will vary between certain limits and the value of the mine will vary accordingly. If the mine fails because of lawsuits, the engineer cannot be blamed if he has arranged beforehand to have the question of titles referred to lawyers selected by the company and if he has stated all his information upon this subject in his report. If the engineer is not called upon to take full responsibility for the decision as to whether or not the mine he has examined is to be purchased, he cannot be blamed if that decision later proves in error, so long as he has set forth his information clearly and explicitly. Ordinarily the final decision will be made by the board of directors, over whose action

the engineer has no shadow of control; and he should therefore not be blamed if events which he can neither foresee nor influence result in a change in value.

The engineer should positively decline to give any opinion upon the probable price of mining shares within a short future period. He may know, for example, that within a few years the price of zinc shares will be higher than at present, but he would be bold indeed if he were to state outright what the market price of the shares in a particular zinc-producing company is likely to be for the next six months. If he attempted to do so, he would be oblivious to the great number of factors that might cause huge fluctuations in price during even that short period.

While it is true that, in general, most mining shares tend to be overvalued on the market, the engineer should not state that shares in any particular company are either overvalued or undervalued at a certain time unless he has made a careful analysis of all the facts. The market price of a given share at a given moment is the product of the judgments of thousands of keen-witted men, many of whom make their living by studying the causes affecting share market values, and if a person buys a share on the stock exchange for a certain price, it is the general consensus of the public at that time that he is paying exactly what the share is worth, perhaps not as an investment but as a speculation.

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Chapter 17

The Valuation of Mining Shares

If the true value of the ordinary mining share, as calculated by the method set forth in chapter 8 of this book, is compared with the average market price of this share over a period of several years, it will be discovered that the price at which the share is sold in the market at most times is much higher than the value indicated for it by a careful engineering estimate. That is, the public consistently tends to overvalue mining shares, and is frequently willing to risk its money in this speculative business for no greater return than would be received from investment in public utilities shares or some other equally sound industrial stock. Although a technique exists for determining in a large degree what should be a reasonable price to pay for a certain mining share, the ordinary American buyer would seem to refuse such help and to look upon the purchase of these shares neither as investment nor as speculation, but simply as a gamble. This state of affairs might be mitigated by educating share buyers in the methods by which shares may be valued more intelligently.

RISKS IN VALUATION OF MINES

The following factors all must be considered in setting the risk rate in mine valuation.[1]

I. Geological vagaries largely unpredictable: faults, branches, pinches; variations in wall rocks; variations in dip and strike.

II. Mineralogical vagaries largely unpredictable: variations in content of metal; variations in mineralogical species; appearance of deleterious minerals.

III. Metallurgical vagaries largely a result of II: change in form of processes; new processes; poor result from rise and fall in efficiency of labor.

IV. Gas, water, fire, swelling ground.

V. Unpredictable metal prices with strong probability of over-estimate.

VI. Discovery of new and competing deposits elsewhere.

VII. Strikes and labor and social legislation; combinations in restraint of trade; nationalization of mines; taxes levied without reference to laws of economics; unintelligent regulations; tariffs; revolutions.

VIII. Theft—a pertinent factor in gold, diamond, and silver mines. Fraud by salting of samples.

[1] Hoover, H. C., *Principles of Mining,* p. 182.

IX. Errors in engineering: errors latent in the sampling method; errors latent in the analytical method; faulty estimates of recovery; faulty estimates of costs of equipment and operation; faulty estimates of price variation.

X. Unforeseen infringements of patents on process and apparatus.

It has been pointed out in an earlier chapter that a mining property is a wasting asset. That is, it creates nothing in the sense that a farm yields crops. It is a storehouse which, once exhausted, can never be replenished. Even the plant and equipment installed will go on the scrap heap at the end of the mine's life. It is absurd to place such a property in the same investment class as the ordinary railway or public utility company, the assets and goodwill of which are expected to have a constant value or even to increase, and which therefore do not need to be redeemed within a few years. A part of every mining dividend must be considered as a capital return, while the yield from a public utility share—unless the company has had extraordinary reverses—may be considered as net return to the investor. Yet market records show that many buyers of mining shares overlook the fact that capital put into mines begins to shrink from the moment when the first ton of ore is taken out and that these people tend to put out their money with the same assurance whether or not the type of security involves greater or less risk, and regardless of what interest rate it may pay or whether it pays any dividends. The interest rate should be greater as insecurity of investment increases, as can be shown by calculating the present worth of three classes of securities involving different degrees of risk: a government bond, a share in a large telephone company, and a share in a mine.

PRESENT VALUE OF TYPES OF SECURITIES

Present value of a government bond.—A bond is a promise to pay a certain principal at a certain future date, and meanwhile to make periodic interest payments of an agreed percentage of the principal. Suppose that the investor is extremely conservative and wishes to put his money into the most stable investment he can find, and is willing to be satisfied with a low interest rate. He might therefore be content to purchase a government bond yielding 4 per cent annually. Interest would probably be paid semiannually, and thus a 4 per cent $1,000 bond would carry coupons in the amount of $20, one of which might be cashed every six months. The present

value of the sound bond, purchased to obtain a yield of 4 per cent, would obviously be its face value, or $1,000.[2]

If the bond was purchased at a premium or a discount, the yield would be less or greater than this percentage, and the present value could be derived from compound interest tables.

Present value of a public utility share.—A share of stock differs from a bond in that it is a part-interest in a business rather than a promise to pay. Moreover, the share entitles the owner to a perpetual claim on the profits of the business, but it does not call for repayment of capital at any specified time and the owner does not have the status of a creditor. The amount of dividends that he receives is dependent upon the success of the business, which is in turn the product of a great many factors which may be influenced by the risks and hazards encountered in the venture. Certain fields of industry may be considered to offer fewer hazards than others. Shares in a well-established public utility company, with a steady or increasing demand for its services, a fund of goodwill, a large surplus capital, and assets of long usefulness, may be thought to have considerable stability, and in some exceptional cases may offer almost the same security to the investor as does a government bond. Some large coal- and iron-mining companies, and certain mining and smelting companies whose operations are extensive and do not depend upon the continuance of one or two mineral deposits, approach this stability and may therefore be regarded as investments for the conservative business man. However, most mines producing precious and base metals, especially in the early stages of their exploitation, cannot be put in this class, as the hazards ordinarily encountered are greater and the success of the venture is more speculative.

Suppose, now, that the investor desires to put his money into a business which may return a larger annual yield than does the government bond at 4 per cent and in order to gain this increased yield is willing to incur a slightly greater risk. He may then consider the purchase of shares in a railway or public utility corporation in the hope of obtaining, say, 6 per cent on his money; but he has no defi-

[2] The foregoing naïve paragraph was written in 1932 and reflected a lifetime of education by frugal and careful forebears in the gospel of the stability and integrity of the United States 4 per cent gold bond. This doctrine originated in the piggy-bank savings of the small boy and advanced through the first savings bank account. It was a part of the religion of the American people—the "cult of the 4 per cent." The value of that 4 per cent bond in 1932 was not $1,000 as stated in the foregoing paragraph, but $600 or less (see page 184)—an error of only 40 per cent. The engineer who wrote the paragraph had no way of sensing the coming of a new deal.

nite assurance that this rate will be maintained, for the dividends may be increased or, on the other hand, may be cut or passed altogether. However, assume that he is willing to take the chance and decides to purchase some common shares in a large telephone company which for the past ten years have been regularly paying $6 annually on a par value of $100. The present value of such a share, bought to obtain a yield of 6 per cent (and assuming, as is customary, that this yield will be perpetual) would obviously be its par value of $100. If the investor paid less than this sum he would, if dividends remained the same during the time he owned the share, be obtaining a greater yield on his money. If he paid more, he might be receiving a yield on his money less than commensurate with the risk incurred, and therefore might better have put his money in a firmer investment, such as a municipal bond. The comparison made when choosing between the two types of investment cannot be reduced to any formula. The investor merely estimates the future yield on each and the respective risks incurred, and "senses" a preference.

Some large public utility companies, during periods of expansion, issue to their stockholders "rights" which are virtually an increase in dividends. For example, the company might in a certain year increase its capital stock by 20 per cent and allot to the holder of five shares the privilege of purchasing one new share at a par value of $100. If the market price of the share at the time happens to be $150, the share purchased by the stockholder from the company at par can immediately be sold in the market at a profit of $50, and therefore the right to purchase might be considered as a dividend of $10 a share. (Rights are negotiable and sell for a price approximately equal to the difference between the price offered to the stockholder and the current market price.) The yield on shares in companies issuing these rights should therefore be considered to be the sum of dividends per share plus the sum per share realizable from the sale of such rights.

It should be noted that when an investor who is contemplating the purchase of a share makes an estimate of its present value his concern is less to know what has been the yield on it in the past than to make a reasonable inference as to what will be the yield in the future. Past yield is therefore far from being an infallible index to future yield and during boom times may be altogether disdained by those who feel that the "new era" will bring a great enhancement of yield; these people presumably value shares on the basis of the in-

creased dividends they expect. However, the dividend record of a company, when combined with a study of its present financial status and of the business outlook for the industry, will result in the best estimate that can be made of the probable future yield. A still closer guide to future yield than dividend per share is current earnings per share. This figure may be obtained from the current financial statement of the company and is an index not of the amount that has been declared and paid in the past but of the amount that will be paid—or reinvested in the company—at the next dividend period.

When an investor purchases a public utility share solely on the basis of yield he is of course assuming a perpetual life for the company's activities and does not contemplate setting aside part of the yield as a return of capital. To assume that a company's assets will be maintained forever undiminished is theoretically unjustifiable—thirty years ago, persons buying and selling shares in street railway companies probably gave no thought to the possibility that the value of the assets of many of these companies would shrink in the degree noted at the present time—but owing to the extreme difficulty of making any reasonable estimate of the future life of well-established enterprises it is usual to assume perpetual life for them and to consider as negligible the need for redeeming capital by a small annual sinking fund. In other words, the buyer assumes that he can sell his share, whenever he wishes to recover his capital, for as much as he paid for it. In any short-lived enterprise such as the extraction of ore from a mineral deposit, however, the redemption of capital during the life of the business becomes of very great importance.

Present value of a mining share.—An example to illustrate the calculation of the present value of a mining share has been given in chapter 8 (pp. 156–57). In that place it was also stated that a yield of 10 per cent on the outlay, in addition to amortizing capital at 4 per cent annually, is the lowest rate that should be expected on any mining investment, and that many mining businesses do not begin to be attractive until there is strong geological evidence that the production will insure dividends of 25 per cent or more.

The formula used to determine the present value of a mining share requires that two factors be given known or assumed values. These factors are (1) the life of the mine, and (2) the expected annual dividend per share. All the labors of the valuing engineer are undertaken with the object of making a rational estimate of these all-important factors. Roughly speaking, it may be said that the period of productivity of a metal mine lies between zero and forty

years, and that the rate of return on capital outlay should be not less than 10 per cent; but there is no royal road to discovering what figures should be used for these two factors in the case of any particular mining enterprise. A number of sources of information exist that will enable an experienced person to estimate these needed factors with more or less validity, and these sources will be described in a later section of this chapter. However, it is seldom that any of these sources are consulted by the average American buyer of mining shares. The truth is that those who speculate in mines seldom know or care what the true value of a share may be. They would seem to hazard their money on mining shares as they hazard it on the turn of a card, buying shares on a gamble that they will rise in value and selling for fear of a slump. This tendency to gamble in mining often leads to erratic fluctuations in share quotations that do not correspond to demand for mining products; that is, when metal prices are high the public often overvalues mining shares, and when metal prices are low they sometimes undervalue them. It is, of course, to be expected that shares in mining *prospects*, whose values are almost wholly speculative, should be considered as rank gambles; but the public seems to yield to this tendency to gamble even in shares in mines that have reached a stage of fairly stable development and constant production.

Comparison of three types of security.—Differences in the three types of security referred to in this section may be demonstrated by calculating the present value of a good bond, a good public utility share, and a good mining share. Assume that the same amount of money is available for investment in each case, but that the desired yield will be commensurate with the risk assumed. Thus:

A good bond

Face value, $100
Interest rate 4%, or $4 per year
Desired yield on investment, 4%
(Since it is presumed that capital will be repaid at maturity, no amortization is required)
Then present value = *$100*

A good public utility share

Par value, $100
Dividend rate, $6 a year
Desired yield on investment, 6%
If yield is assumed to be perpetual, then present value = *$100*
If it is assumed that capital is to be redeemed in 40 years by sinking fund at 4% (factor, 14.18), then present value = *$85.08* ±

A good mining share

Par value, \$100

Dividend rate, \$6 a year

Desired yield on investment, 15%, to cover risks inherent in the business

Assuming that capital is to be redeemed in 40 years by sinking fund at 4% (factor, 6.21), then present value = *\$37.26* ±

A comparison of the present values here calculated will serve to reveal the importance of the two factors of desired yield on investment and life of the enterprise during which capital should be returned.

OVERVALUATION OF MINING SHARES

Mining a speculative business.—Are mining shares investments, speculations, or gambles?

An "investment" may be defined as the outlay of capital for a period in the expectation of receiving back this capital at the end of the period, meanwhile receiving a regular income from it. It should not be loosely used as a synonym for "speculation," which is the outlay of money in an enterprise offering the hope of high reward in return for the incurring of high risk. The investor of the type purchasing gilt-edged bonds

> looks more to the protection of his principal than to the enhancement of its value; he has an eye to the regular dividend rather than to market fluctuations, even of a favorable character; he eliminates risk as much as possible and is content at the end of a period to receive his principal intact, having received interest regularly in the meanwhile. The speculator looks to a quick profit from a rapid rise in the market-value of his principal; the element of risk is distinctly involved, but the risk of a "speculation" is compensated by the extra gain; the dividend is subordinated to the profit to be made by selling the share at a higher price, and becomes important mainly as it enhances the value of his principal; the "speculator" does not care even if dividends cease, if for other reasons his shares appreciate.[8]

The speculator risks all in the hope of gaining much. If he recognizes the degree of risk he assumes and is willing to stake his capital on the outcome, he cannot be censured for thus putting at hazard any amount he can afford to lose; in fact, were his adventurous spirit to disappear from the financial scene most of the industrial enterprises of the modern world, including mining, would be at a standstill. Moreover, money used in speculative enterprises may be more remunerative than that more safely employed in conservative investments, and hence in a sense more economical. But when a man

[8] "Speculation and Investment," (edit.) *Mining Mag.*, March 1910, pp. 179–80.

lays out his money in financial transactions dependent for success chiefly upon chance or unknown contingencies he becomes a gambler.

It is not always easy to classify any particular venture in this manner. T. A. Rickard prefers to consider the distinction as largely subjective:

> A Boston school-teacher may buy the shares of the Great Wildcat Extended as an "investment," whereas a Wall Street broker recognizes that it is highly "speculative," and a Nevada engineer knows that it is a rank "gamble." These terms are relative; they connote a crescendo of risk; even an investment has a slight element of risk; a speculation has more; a gamble most.[4]

There is a consensus among most mining engineers that mining shares, at best, are speculations and never investments. At worst, they are swindles and not to be dignified by the name of "gamble," for the buyer is certain to lose. Perhaps the only writer of note who seems to admit mining shares to the status of investments is J. Parke Channing,[5] but his opinion is qualified by a number of reservations. John Hays Hammond says:

> Speaking with a proper appreciation of the importance of the statement, I have no hesitancy in expressing the opinion that, conducted upon the right basis when extended over many operations, there is no business with which I am familiar, that offers such attractive and at the same time such safe investments as the mining industry.[6]

The pith of this statement lies in "the right basis," which means careful reports by qualified engineers, and "extended over many operations," which connotes the employment of large sums; both of these requisites are out of the reach of the man of ordinary means, and therefore Mr. Hammond might be considered as taking much the same attitude as James Douglas, whose advice is: "Never invest in any mining enterprise what you cannot conveniently afford to lose."[7] The matter is summed up by Herbert Hoover:

> It should be said at once to that class who want large returns on investment without investigation as to merits, or assurance as to the management

[4] "Mining: An Investment, a Speculation, or a Gamble?" *Min. Sci. Press*, April 19, 1919, pp. 523–27.

[5] "The Safety of Judicious Mining Investments," *Engin, Min. Jour.*, Jan. 22, 1910, pp. 211–13.

[6] "Suggestions Regarding Mining Investments," *Engin. Min. Jour.*, Jan. 1, 1910, p. 11.

[7] "Mining Investments," *Engin. Min. Jour.*, Jan. 15, 1910, p. 157.

of the business, that there is no field in this world for the employment of their money at over 4%.[8]

A little reasoning will show that the purchase of shares in almost all mining businesses must always remain a speculation and therefore these shares must necessarily be overvalued by the public. A mining share is comparable, from one point of view, to a lottery ticket, and every buyer hopes to win the grand prize; therefore, to the intrinsic value of the share must be added a value to represent the chance of reaping a windfall through the discovery of a bonanza.

Overvaluation by the public.—Several examples may be given which show how mining shares are commonly overvalued by the public. For instance, here is a share that has been quoted on the stock market for some time at $40. For several years the dividend on the share has been $5 per annum. Making use of the nomograph, Figure 5, the present value of such an annuity may be calculated for several interest rates and several periods of life, as shown in Table 11.

TABLE 11

PRESENT VALUE OF $5 ANNUITY

Assumed Life in Years	Required Interest Percentage	Nomograph Value of $1 Dividend	Present Value
10	10	5.46	*$27.30*
10	20	3.53	*17.65*
20	10	7.49	*37.45*
20	20	4.28	*21.40*

The four sums of money calculated in Table 11 show what would be reasonable prices for the share under different conditions. If one is willing to be content with a meager 10 per cent return and believes that the mine will continue to pay dividends undiminished for the next twenty years, then the market price of the share is only slightly higher than its estimated present worth; but an experienced buyer of mines would be extremely hesitant in accepting such a return and such a risk. If one's instinct for caution suggested that an assumed life of ten years and a return of 20 per cent are more in keeping with circumstances, then he would discover that the share is being dealt in at more than twice $17.65, the sum he would be justified in paying on the basis of present worth of the $5 dividend. If he nevertheless purchased the share at $40, he would in fact be

[8] *Principles of Mining,* p. 184.

betting $22.35, the difference between market price and present worth under these conditions, that favorable developments of one sort or another would bring about an increase over the present dividends, or a boom in the shares of the mine; whereas, if the mine had been worked for some years, it would be more than likely that dividends would on the contrary diminish.

The absurdity of comparing a public utility share, with a "life" of many years, on the same basis as a share in a mining company whose deposits may be exhausted in four or five years may be shown by a simple illustration. Suppose a person has $100 to invest and has the choice of putting it into a public utility share which will in all probability pay 6 per cent annually or of buying for the same price a mining share which may be expected to pay 6 per cent annually, redeeming capital at 4 per cent. Assume that the productive life of the public utility company will be forty years—it might easily be a hundred. Then, in order to compete with the public utility investment on the basis of yield, *the mine would also have to have a life of forty years;* and only a few mines in history have had such a period of production. It may therefore be stated that the buyer of shares, if he mentally puts these two classes of investment on a par with each other in regard to annual yield, must also assume that the mining company will have the same financial stability during the same period of life as the public utility company; and this is far from justified by experience.

The opinion that mines are, on the average, consistently overvalued by the public is given by Heath Steele[9] as his conclusion after making a study of forty copper stocks over a twelve-year period. Twenty of these were in non-dividend-paying mines, and this group of prospects was given a total market valuation, as indicated by the high quotations during the period, of $125,392,000; "but when optimism gave way to pessimism, as recorded by the lowest quotations, the public's opinion of these mines depreciated $114,439,000 and the appraisal was only $10,953,000 for the group." In order to realize the expectation of the public these mines would have had to develop a production equal to that of the whole Lake Superior district. Even the dividend-paying group of mines was greatly overvalued in the market. High quotations during the period indicate that $1,063,000,000 was the public valuation of these mines, or 366 per cent over the amount of $228,306,000 derived from the low

[9] "Valuation of Mines by the Public," *Min. Sci. Press,* March 8, 1913, pp. 379–80.

quotations. If the high quotations be taken as giving the valuation of the properties, dividends paid during the period amounted to 1.71 per cent on the investment; while if the lowest public valuation be taken, these mines, which included the most profitable American copper properties of the time, yielded during the twelve-year period a return of 7.95 per cent. If $562,000,000, a rough average, may be taken as indicating the real valuation placed upon these mines by the public, the average annual dividend for a six-year period was only 4.15 per cent. It would therefore seem that at that time the public was buying mining shares on the same basis as railway shares, for example, even though a mine is worth most at the beginning of the dividend-paying stage and rapidly depreciates in value thereafter. That this surprising state of affairs has not been drastically improved since the time Steele's study was made is indicated by an examination of Table 12, which shows that—although a few conservative mining businesses with wide holdings may be found whose shares are undervalued on the stock exchange, especially during periods of heavy deflation—mines as a whole are still consistently and tremendously overvalued by the market quotations.

Table 12 lists a number of dividend-paying mining companies and shows the high and low quotations for the shares during the years 1927 through 1932, the average yearly dividend paid on each share, and the present values of these shares at two rates of interest and three assumed periods of life. The data given are, of course, insufficient for the purpose of placing a value on the shares of any of the companies at a particular time; the figures are chiefly valuable in showing the wide range of share prices during the past few years, and in revealing the great disparity between high record prices and the present value of every share in the list, even conceding that the life of the property will be 40 years and that a meager 10 per cent return on capital is sufficient.

The great mines of the Rand were greatly overvalued at the time of their initial development. They were considered by the public to possess an almost infinite life expectancy, and shares were purchased on the same basis as though they were conservative investments such as government bonds.

When the gold-bearing banket of the Rand was sampled and tested, when the orebodies at Johannesburg had been measured and assayed, when the metallurgical reduction of the ore had been decided upon, it was stated, confidently, by many first-rate engineers, and by more promoters, that here at last we had gold veins that were as regular as coal seams and mining enterprises that were as safe as British Consols or United States bonds. So

TABLE 12

DIVIDEND-PAYING MINING STOCKS (COMMON) LISTED ON NEW YORK STOCK EXCHANGE, 1927–1932, INCLUSIVE*

Stock (Common)	Average Annual Dividend, 1927–32, Inclusive	High Record		Low Record		Present Value of Dividend					
						10-Year Life		20-Year Life		40-Year Life	
		Price, Dollars	Year	Price, Dollars	Year	10% ($5.46)	20% ($3.53)	10% ($7.49)	20% ($4.28)	10% ($9.05)	20% ($4.75)
Alaska Juneau Gold Mining Co.	$0.17	20⅛	1931	1	1928	$ 0.93	$ 0.60	$ 1.27	$ 0.73	$ 1.54	$ 0.81
American Metal Co., Ltd.	1.85	81¾	1929	4⅞	1931	10.10	6.53	13.86	7.92	16.74	8.79
American Smelting & Refining Co.	7.81	188¾[a]	1927	17½	1931	42.64	27.57	58.50	33.43	70.68	37.10
Anaconda Copper Mining Co.[b]	2.98	140	1929	3	1932	16.27	10.52	22.32	12.75	26.97	14.16
Andes Copper Mining Co.	0.90	68⅜	1929	1⅜	1932	4.91	3.18	6.74	3.85	8.15	4.28
Butte Copper & Zinc Co.	0.08	12¼	1928	½	1932	0.44	0.28	0.60	0.34	0.72	0.38
Butte & Superior Mining Co.	1.00	16¾	1928	½	1932	5.46	3.53	7.49	4.28	9.05	4.75
Calumet & Hecla Mining Co.	1.75	61⅞	1929	1½	1932	9.56	6.18	13.11	7.49	15.84	8.31
Cerro de Pasco Copper Co.	3.56	120	1929	3½	1932	19.44	12.57	26.66	15.24	32.22	16.91
Chile Copper Co.	2.34	127½	1929	5	1932	12.78	8.26	17.53	10.02	21.18	11.12
Dome Mines Co., Ltd.	1.11	14⅛	1927	6	1929	6.06	3.92	8.31	4.75	10.05	5.27
Granby Consolidated Min., Smelt. & Power Co.	2.96	102⅞	1929	2⅜	1932	16.16	10.45	22.17	12.67	26.79	14.06
Greene Cananea Copper Co.	2.04	200½	1929	6½	1932	11.14	7.20	15.28	8.73	18.46	9.69
Homestake Mining Co.	7.91	138	1931	60	1927	43.19	27.92	59.25	33.85	71.59	37.57
Inspiration Consolidated Copper Co.	1.17	66¾	1929	¾	1932	6.39	4.13	8.76	5.01	10.59	5.56
International Nickel Company of Canada	0.47[c]	72¾	1929	3½	1932	2.57	1.66	3.52	2.01	4.25	2.23
International Silver Co.[b]	4.58	198	1927	7½	1932	25.01	16.17	34.30	19.60	41.45	21.76
Kennecott Copper Corporation	3.29	156[a]	1928	4⅞	1932	17.96	11.61	24.64	14.08	29.77	15.63
Magma Copper Co.	2.75	82½	1929	4½	1932	15.02	9.71	20.60	11.77	24.89	13.06
Miami Copper Co.	1.48	54½	1929	1½	1932	8.08	5.22	11.09	6.33	13.39	7.03
National Lead Co.	5.13	210	1929	45	1932	28.01	18.11	38.42	21.96	46.43	24.37
Nevada Consolidated Copper Co.	1.43	62⅞	1929	2½	1932	7.81	5.05	10.71	6.12	12.94	6.79
Park Utah Consolidated Mines	0.36	14½	1928	⅝	1932	1.97	1.27	2.70	1.54	3.26	1.71
Patino Mines & Enterprises Consolidated, Inc.	1.66	47¾	1929	3⅛	1932	9.06	5.86	12.43	7.10	15.02	7.89
Phelps-Dodge Corporation	6.08	199½[a]	1928	3⅞	1932	33.20	21.46	45.54	26.02	55.02	28.88
St. Joseph Lead Co.[b]	2.21	94	1929	4⅝	1932	12.07	7.80	16.55	9.46	20.00	10.50
U.S. Smelting, Refining & Mining Co.	2.36	72⅞	1929	10	1932	12.89	8.33	17.68	10.10	21.36	11.21
Vanadium Corporation of America	2.63	143½	1930	5¼	1932	14.36	9.28	19.70	11.26	23.80	12.49

* Quotations for 1927–1931 from Poor's *Industrial Companies*, 1932; for 1932 from *The Annalist*, January 20, 1933.

[a] Old stock. [b] Has also issued, during the period, rights to purchase, which may be considered as an extra dividend. [c] 1928–32 only.

there was a boom; this was in 1895 and at recurrent intervals in later years. The shares of the mining companies went kiting, naturally, for they were capitalized on earnings estimated at 20 to 25 per cent, and when the public had been filled with ideas of a safe investment, of a sure thing, of a form of gold mining the like of which the world had never seen, they naturally thought that a return of 4 or 5 per cent was enough. Capitalists and their followers talked of amortization; actuaries' tables were brought into service; the nicest kind of elaborate calculations were made of the life of the mines, of their ability to repay the capital invested and of furnishing the required interest on the "investment." Investment, of course, no more of your silly gambling in American or Canadian mines; in South Africa they had the real thing, beyond peradventure. It was as good as the Bank of England, and more profitable.[10]

The truth was that these mines of the Rand proved to be as disappointing as most other gold mines; the ore was patchy and erratic, the 20 or 25 per cent dividends allowed for little more than return of capital, and a terrific slump in share values wiped out the paper profits of thousands of speculators.

Any American mining engineer doing business in London is sure to hear mention—seldom without bitterness—of the Emma Silver Mine, the classic case of overvaluation and overpromotion of an American mine in England. There has probably never been a mine promotion that attracted so much attention, chiefly because of the character of the British promoter and because the United States Minister and a United States Senator were also concerned in the sale. The Emma Mine was discovered in Utah in 1870. Professor B. Silliman of Yale reported, after an examination, that the mine would eventually come to be regarded as one of the great mines of the world; probably he had good grounds for this belief, but it later turned out that the deposit was pear-shaped and cut off suddenly, without any extension that could be found. Senator William M. Stewart, of Nevada, assisted in the sale of the mine to an English company, and testified that he made $270,000 from it. The mine was sold for a million pounds sterling, a price which even at the time was criticized as being unjustifiably high, and the English company was capitalized at that sum. The promoter who floated the property in London was Baron Grant, the pioneer of modern mammoth company promotion. It is said that the origin of his success was his notion of obtaining lists of the clergy, widows, and other small yet sanguine investors. His career may be compared to that of Whitaker Wright, whose scandalous operations during the latter years of the

[10] "Speculation or Investment," (edit.) *Min. Sci. Press*, Oct. 12, 1907, pp. 442–43.

nineteenth century may be studied as dangerous examples of napoleonic mine promotion.[11] Grant floated a host of shaky schemes, of which the Emma Mine was the most notorious. In the prospectus issued in 1871 the profits were estimated at £800,000 per annum; but the crash came shortly, and after about ten years of litigation between the directors and the shareholders the "investors" received only a shilling for their £20 shares. An unfortunate feature of the promotion was the inclusion of the name of General Robert C. Schenck, United States Minister. He seems to have been convinced of the value of the mine, became a director of the British company, and invested in 200 shares at £20, selling some of them subsequently at £30, but losing on the whole $50,000 to $60,000, according to his testimony before a Congressional committee.

The tricky nature of the mining business is emphasized by the fact that within the last year a young engineer by the application of sound conceptions as to the geologic causes of faulting has been able to pick up the broken-off vein and the Emma Mine is in a fair way to be brought back to life.

Many other instances can be cited to show that on the whole the valuation of the public, as reflected in the market prices of shares, is greatly in excess of the valuation that would be made by an experienced engineer.

Criticism of engineering method of valuation.—It may be objected by some that the technique of evaluating a mine recommended herein is too conservative, and that refined calculations making use of carefully estimated financial factors may be upset completely by sudden changes in metal prices, changes in tenor of ore, or the like. The possibility that future developments will alter matters, however, does not release the engineer from the obligation to make a valuation based on the facts in hand, or from attempting in every way to minimize the risk inherent in the business of mining. All he can do is to make an intelligent estimate of risk from factors at hand, for the chances of the future are on the knees of the gods. The soundest and most widely used method of mine valuation is the present-value method based on the Hoskold formula, and this is the method advocated in this book. It may be said in addition that this basis of valuation is recommended by an experienced engineer for use by younger engineers who wish to succeed in their profession and make

[11] See account in *Dictionary of National Biography*, Second Supplement, Vol. 3.

reputations by reporting favorably on mines that have legitimate chances of paying profits. It is much less damaging to the reputation of a young engineer to neglect one or two fairly good mines than it is to ally himself in the promotion of a mining business that is doomed to failure.

It will also be objected that if this scientific method of valuation were everywhere instituted the discovery and development of mineral deposits would be crippled and the mining industry would come to a halt. This is obviously false. The method is in wide use today. If production diminishes in the future, economic pressure will push up metal prices to the point where the rewards of mining will be greater and the risks lessened, thus encouraging prospecting, and speculation and investment in mines.[12] There might be fewer mines operating than at present, but all would be on a firmer financial foundation and, on the whole, the world supply of a metal would probably be produced at a cost more in keeping with its market value. It is likely that under the present system of hit-and-miss speculation more capital is expended on mining than is recovered in the form of metal; that is, the profits from the good mines are less than the losses from the poor mines and shady enterprises. Indeed, it is probable that the world's gold, for example, has always been obtained at a cost greater than its value. But at all events, the objection is groundless, because there is no likelihood that the mining business will ever be put on the same investment footing as public utility development.

SOURCES OF INVESTMENT INFORMATION

There are a number of sources of information to which the prospective buyer of mining shares may go when seeking the facts bearing upon the two factors needed for determining the present value of the share. Each of these factors—i.e., the estimated life of the mine, and the expected dividend rate—is in turn a composite of a number of factors representing future risk.

In England, a considerable body of financial information concerning the company is required by law to be placed on record, so that it is a comparatively easy matter for the prospective investor to obtain statements that will guide him when making a decision;

[12] This statement is based on the hypothesis that democracy and the profit motive in human affairs will endure; and while it is entirely logical, it may be negated in large part, or wholly, by the extension of collectivism.

moreover, the directors of a company are liable to prosecution if an inaccurate prospectus is issued. In the United States, until the passage of the Federal Securities Act in 1933, there has been no such adequate legal requirement that the public be given full information concerning a company's operations, and some company officials are averse to issuing any financial statements that are not required by law; therefore it has been more difficult to obtain reliable facts that would be of service in forecasting the values of American shares. In this section the more accessible sources of information for investors will be mentioned.

The American Mining Congress in 1910 passed a resolution asking that full information concerning mining companies be put on public record. This resolution, a result of the efforts of E. S. Mendels, agent of the New York Curb Market, was an attempt to protect unwary share-buyers and to put mining speculation on a more factual basis. Although no steps have since been taken to institute legal requirements of this sort, the resolution is worth quoting in full, both as giving an expression of the desire of the Mining Congress to promote intelligent share-buying and as giving a complete list of the requisite facts to enable the buyer to aid worthy mining enterprises that have legitimate chances of success:

> That in view of the many attempts that are made to float on the unsuspecting public the securities of mining, oil and other industrial corporations, which are classed as wildcats, fakes and swindles,
>
> Be it therefore resolved that it is the sense of this congress that the following requirements for public information should be made in all cases and filed with the proper county or State authorities and such place of filing be stated when issuing circulars or other matters relating to all companies who desire capital for the furtherance of their enterprise:
>
> (1) Title (in full); (2) situation; (3) product of company; (4) when and where incorporated; (5) general office; (6) transfer agency, where situated; (7) registrar of stock (must be corporation), where situated; (8) stock, common shares authorized; (9) par value of same; (10) stock, common shares outstanding; (11) shares in treasury; (12) stock, preferred shares authorized; (13) par value of same; (14) stock, preferred shares outstanding; (15) shares in treasury; (16) dividends, rate, when declared, where payable, last dividend paid and amount; (17) bonds, state class of mortgage, when dated, when due and interest rate, when and where payable; (18) bonds, total issue authorized; (19) bonds, amount issued; (20) names of officers and directors, address and personal references of each; (21) numbers and denominations of stocks or bonds on which transfer has been stopped and the cause thereof; (22) statements of assets and liabilities, earnings and expenses, signed by an officer of the company, with seal attached, and sworn to before a proper court officer or notary public; (23) engineer's report, certified and sworn to; (24) certified copy of the charter;

(25) maps of the property; (26) all matter printed or otherwise relating thereto; (27) certified copy of the leases; (28) confirmation of the titles, etc., certified; (29) a full and detailed balance sheet.

Resolved, that officials of companies, promoters, engineers, bankers, brokers or newspapers making misstatements of facts be reported to the Federal or State authorities for criminal action and that the use of the mails be refused and fraud orders issued for the protection of the public.

In the absence of reliable public records covering the points listed in the resolution, the investigator has had to turn to other sources of information. The most important of these sources are: financial yearbooks; prospectuses; engineers' reports; market quotations and dividend reports in the press; financial advisers; and annual company reports to stockholders and other periodic financial statements by the company.

Financial yearbooks.—A large amount of information concerning established mining companies is given in the two comprehensive annual financial registers of industrial companies, published by Poor and by Moody. *The Mines Handbook,* published every few years in the United States, describes in some detail the mining companies of the world and in addition to the usual available information on capital and financial condition includes particulars concerning history, geology, development, equipment, and production of the companies' properties. Some 12,000 titles are listed in the index of the latest volume (1931). A similar work, *The Mining Manual and Mining Year Book,* is annually published in England. The information printed in these volumes, although not all of it is guaranteed by the compilers to be correct, is the best single source for obtaining records of operations and finances of mining companies, especially those owning well-established properties.

Prospectuses.—In the United States, where company prospectuses are not regulated by adequate statutes and the person or company issuing a false statement can be attacked only by proving attempt to defraud, it is almost impossible for the prospective investor to make a sound judgment of share values from a perusal of such a document. It is well to remember that the attitude of the author of a prospectus is not that of the impartial reporter of facts. He is, rather, a salesman aiming to attract capital by persuasion, and all circumstances will be interpreted by him in the light most favorable to his cause. One should beware especially of that flamboyant type of prospectus which seeks to "high-pressure" the victim into parting with his cash instantly. Such ballyhoo methods should invariably

be regarded by the reader as he regards the skull-and-bones on the label of a poison bottle.

Engineers' reports.—Who is the engineer? This should be the first question that the prospective investor asks himself when confronted with a report, or extracts from a report, by a so-called expert. If the name signed to the report is that of a reputable and experienced geological and mining engineer who has examined the property recently, the reader may be sure that the engineer's estimates are many times more accurate than he himself could make them; but the risk of management and the risk of changing metal prices still remain to be allowed for in the final valuation of shares.

Current quotations and dividend reports.—Stock-market quotations and dividends on mining shares are reported in the columns of the daily press, and in such financial periodicals as *The Bank and Quotation Record, The Commercial and Financial Chronicle,* and *The Annalist,* all published in the United States. High, low, and closing quotations for the month may also be found in the *Engineering and Mining Journal,* and in *The Mining Magazine* (London). These two mining periodicals also print news of developments and dividend payments by various companies. The financial yearbooks named previously contain high and low quotations and dividend payments, over some years, for many of the companies described therein. Dividend rate is required, of course, if the present-value formula is to be applied in determining what will be a fair price to pay for a share.

Financial advisers.—Investment bankers, brokers, and others professionally concerned in the buying and selling of shares are often in position to give excellent advice upon the desirability of purchasing mining shares, and these men should be consulted before any decision is made. Particularly helpful is their knowledge of the reputation of the company and the men who control its affairs. Financial advisers will usually not recommend the purchase of the great majority of stocks.

Periodic financial statements.—The financial report of a mining company, unless it contains a statement of the status of operations in considerable detail, is not likely to be informative to one seeking to evaluate the company's shares, even though he is extremely skilled in the interpretation of accounting records. In the first place, the accounting methods of various companies differ markedly and there

is no standard practice for the handling of items such as depreciation, depletion, capital expenditure, development, and surplus. Again, the values shown in a balance sheet are cost values or book values, and these give no evidence of the actual present value of the property. Unless the profit-and-loss statement and balance sheet are accompanied by a full statement of remaining ore reserves, the financial report cannot give any clues to the life of the mine or the future yield, except in so far as current earnings indicate what the probable dividend for the period will be. Moreover, the statements appearing in annual reports to shareholders are likely to picture the situation in its most favorable aspect, and sometimes these statements are even made in a form intended to mislead or deliberately to misrepresent the true state of affairs. Finally, accountants are agreed that strict accuracy in a balance sheet is impossible. "A balance sheet is not a statement of facts, but rather an expression of opinion," says one writer; and another has said: "Not more than 10 per cent of the items in any average balance sheet are, or can possibly be, facts that are capable of being absolutely tested." Even a professional accountant, in order to obtain a clear understanding of the true financial position of a concern, will require a series of financial statements extending over several years and will also probably need to obtain information from company officials concerning many items not segregated in the statement. It is therefore hopeless to expect that the engineer or any other interested reader will be able to dissect a company's position by a glance at the financial statement. However, some understanding of the meanings of items presented in profit-and-loss statements and balance sheets is required of the engineer in his administrative capacity, and in connection with allowable deductions from federal income tax payments; and these will be discussed in more detail in their proper places. Facility in interpreting financial statements comes with practice, and the student possessing an elementary knowledge of accounting principles, supplemented by the reading of special discussions such as the excellent paper by Henry B. Fernald,[18] should be able to derive a considerable amount of valuable information from an examination of periodic company reports.

[18] "The Financial Report of a Mining Company—Its Content and Meaning," *A.I.M. & M.E. Tech. Pub. No. 108,* 1928.

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Chapter 18

Fakes and Fallacies

The engineer must continually be on guard against pseudo-scientific schemes of a thousand sorts, and it is frequently his privilege to be able to expose many of the frauds and fallacies that have drained the pocketbook of the American public of billions of dollars. These schemes range from confidence games of the most criminal kind to the visionary and fallacious inventions of self-deluded cranks. The atmosphere of the mining industry in particular seems to furnish pabulum for an extraordinary growth of such schemes, in addition to the comparatively simple fraud of mine salting mentioned in chapter 4; and therefore the detection of fakes and fallacies of all sorts is part of the daily work of many mining engineers, especially those who are located in cities as confidential advisers and consultants. The engineer working in the field, however, cannot hope to evade encounters with a number of the schemes, devices, and fabulous stories that will be given brief mention. Only the more common fakes, fallacies, and delusions can be listed, for the ingenuity and fertility of the human mind in devising enticing methods of squandering capital is inexhaustible. If the history of human greed and gullibility were written—in five hundred volumes—and known to everyone today, new delusions and new projects for winning sudden wealth would crop up tomorrow.

ORE-HUNTING INSTRUMENTS

For centuries men have sought to aid their prospecting endeavors by the use of instruments of one sort or another. It is only lately that such instruments are attaining any degree of precision, through the application of geophysical science. For some years the dip-needle has been used to locate magnetic orebodies, and the recent researches of geophysics in using electrical, gravitational, seismic, and other methods in the quest for mineral deposits have shown fair degrees of accuracy in their limited fields of application. Surveys by

such methods, however, are usually very expensive and far from infallible, and it is not likely that geophysical prospecting will soon supplant all other methods of locating ore deposits; although, it is true, some of the instruments developed are valuable additions to the engineer's tool-box. Their greatest successes have been in the petroleum field.

The variometer and the torsion balance of the geophysicist are based on well-known scientific laws. Such is not the case with a number of more spectacular ore-hunting instruments, some of which go back to the earliest days of mining. Among these devices and gadgets which may be described are the divining rod, the magic pendulum, the doodle-bug, and several other pseudo-scientific contrivances which pretend to be of value in discovering the course and extent of mineral lodes, underground streams, and buried treasure.

The divining rod.—In all parts of the world there are people who profess to be able to locate mineral deposits and underground streams through means unexplained by science. The commonest instrument employed for the purpose is a Y-shaped twig from certain kinds of trees, and this is variously called a divining rod or dowsing rod or *virgula furcata,* while the operators are referred to as dowsers or water-witches.

When making a survey, the water-witch holds one fork of his rod in each hand with the stem vertical and traverses the ground. When he presumably approaches the hidden watercourse the rod is seen to bend downward, sometimes with such force that part of the twig is twisted or snapped across. The claim is made that the same phenomenon will occur as often as the same spot is crossed, even if the dowser is blindfolded or if another expert dowser is employed; and that if a well is dug at the indicated place water will be found. The dowser frequently complains of exhaustion and giddiness, and in some cases the internal sensations felt when approaching a certain spot are so marked that he discards the forked stick and depends upon these sensations alone to discover the supposed locations of underground springs and watercourses. Some men have had such reputations for thus locating water that they have been able to earn part of their living by marking well-sites, and dowsers, both amateur and professional, have been employed by municipal boards and water companies for this purpose. Some wielders of the magic rod also claim to be able to discover with more or less precision the location of mineral deposits of all kinds.

Rhabdomancy, or foretelling the future by the use of rods, is an

ancient practice recalling the staff of Moses and the wand of the vaudeville magician. It differs from the practice of divining the location of mineral deposits by the use of the dowsing rod, but the latter supposition is also one of long standing. In a manuscript left by a mine surveyor in Europe about 1430 there is a brief allusion to its employment, and in 1518 Martin Luther included the use of the rod in his list of acts that break the first commandment. In Münster's *Cosmography,* published at Basle in 1550, there is a picture of a miner using the rod, while another (Fig. 9) appears in the

FIG. 9.—Use of Divining Rod in Medieval Mining. (From *De Re Metallica,* by Georgius Agricola, 1556 A.D.)

great work of Agricola, who gives a clear account of its use by the miners of Saxony and the Harz Mountains. Various woods have been favored for shaping into such rods, notably those of certain fruit trees, thorn trees, the sycamore, the hazel, and the willow; and at different times other instruments have been used for divination

purposes. The list of these includes candle-snuffers, a pair of scissors, a knife and fork, an open book, a bucket handle, two pipes held with the stem of one inside the bowl of the other, pincers, galvanized wire, tongs, pieces of grass, a walking-stick, and even long smoked sausages of the kind known as "Knackwurst." The list of things sought for by these means, aside from water, medicinal springs, and minerals of all kinds, is likewise long, and comprises hidden treasure, coins, strayed animals, underground conduits, points of the compass, criminals, witches, Protestants, submarine mines, jewels, and lost objects of all sorts.[1]

Few subjects have been capable of arousing so much discussion, not only among unprofessional observers but among scientists, as the question: "Is the divining rod a fallacy?" Periodically the columns of the popular press are deluged with correspondence pro and con, especially in Australia, where water is scarce and the dowser is not without honor. Many people who are neither fools nor ignoramuses are agreed that the astounding success of some dowsers argues that there may be virtue in the method. There are several scientific societies, notably in Germany, which were organized to study the subject, and for many years Sir William Barrett, formerly professor of experimental physics in the Royal College of Science, Ireland, collected dozens of authenticated cases of water-finding by use of the rod when all other methods had failed. Rossiter W. Raymond, secretary of the American Institute of Mining Engineers, in a painstaking and well-written report published some years ago concluded that the use of the rod by water-seekers and prospectors sometimes leads to good results, and stated that, in his judgment, investigation reveals "a residuum of scientific value, after making all necessary deductions for exaggeration, self-deception and fraud."[2]

On the other hand, some scientists are prone to pour the vials of scorn upon any believer in the efficacy of the method. These doubters point out that the rod will not work for them, and is therefore useless. They observe that the rod will not dip when held on a bridge or in a boat, when tons of water lies underneath it. They cite numerous cases in which the dowser's claims have been proved illusory, or in which deception has been attempted by charlatans. It is, of course, well to sound the warning that every case in which it is claimed the divining rod has been successful should be examined

[1] Barrett, Sir William, and Besterman, Theodore, *The Divining Rod.*

[2] Raymond, Rossiter W., "The Divining Rod," *Trans. A. I. Min. E.*, Vol. 11 (1882-83), pp. 411-46.

with scientific skepticism and that one should not spend large amounts of money in following the unsupported advice of a dowser; but the use of the method cannot be brushed aside by branding it out of hand as a fake or delusion. A pamphlet issued by the United States Geological Survey dismisses the subject by stating that "it is difficult to see how for practical purposes the entire matter could be more thoroughly discredited"; but the study ignores the uncontrovertible successes recorded by Barrett and others. The fact remains that certain persons appear to be gifted with the luck to locate good wells where engineers and geologists have failed.

A number of theories have been put forward to account for the power of the dowser. Among those that are obsolete are such naïve conclusions as that the sap in the twig causes it to bend "sympathetically" toward the running streams in the earth; that a body of ore is surrounded by an effluvium of corpuscles and the rod bends parallel to their lines of force; that electricity or "animal magnetism" of some sort is in operation; that the talent of the dowser is an all but forgotten savage instinct, a sixth sense such as the homing instinct is supposed to be; and even that angels, or the devil himself, is bending the rod toward the earth. Unconscious muscular action is an explanation favored by psychologists. This action is revealed when a person holds between his fingers a thread weighted on one end and the pendulum thus devised begins to swing rhythmically; if the pendulum is hung from a fixed pin it will not move, and, equally, there is no virtue in the rod that is not communicated to it by the user. A less sound belief is that the dowser possesses the still conjectural faculty of "clairvoyance." Sir William Barrett preferred to think that the diviner is endowed with a "subconscious, supernormal cognitive faculty"; he presumably is aware of the location of the sought object by intuition rather than by reason, and this feeling is accompanied by an intense emotional reaction which communicates itself to the rod. At any rate it is true that the professional water-witch commonly shows good judgment in locating well-sites. His skill may be explained in part by considering him an adept amateur geologist—self-deluded, perhaps, but one who subconsciously takes into account local topography and utilizes the slightest of geologic clues.

The mining engineer is justifiably interested in the divining rod because many times he will be urged to make a decision on the validity of its use in the field. For example, a dowser may report that his rod indicates the existence of a valuable orebody at such a

depth that the exploratory work will call for a considerable sum, and the engineer must decide whether this work will be done. It is quite safe to say that no one should undertake to spend a considerable sum of money to uncover a deposit that exists only on the unsupported word of a dowser. Too many instances are known in which the rod has been an instrument used by a charlatan or has been proved to be grievously in error. It may require great moral courage to advise against the expenditure of money for such purposes. The dowser may sound convincing, but it will cost a great deal to prove him wrong—a most expensive form of refutation.

The magic pendulum.—A ring or other weight suspended by a thread forms the magic pendulum or *pendule explorateur* anciently used for divination and still a favorite toy of those who amuse themselves with table-tipping and planchettes. If swung freely by a sympathetic person it is supposed to spell out words and answer questions. Such pendulums, or plumb-bobs, have been used in modern times in attempts to locate ore deposits, much in the same manner as the dowsing rod is used. The operator observes the direction of the swings of the pendulum, and supposedly by this means establishes a running line. He then goes to the right or left of this line and in a similar manner runs another. At the point where these lines intersect, the deposit is presumed to lie. A comparable instrument, supposed to have been useful in prospecting the Klondike, reposes in the collection of Professor J. E. Coover, Fellow in Psychic Research at Stanford University. This is formed in the semblance of a soldering-iron with a flexible shank, so that when the handle is held in the hand, the loaded head can freely bend toward earth on either side of the operator as he traverses the ground to be surveyed. In the head of the instrument is a cavity in which may be fastened a bit of gold, silver, copper, or other metal, which will "sympathetically" respond to the particular type of deposit sought. Dr. Coover made a number of experiments with various divining instruments in the hands of men who claimed to have discovered rich deposits by these means, but none of them gave any conclusive proof that the use of the device added to the chance of successful location.

Doodle-bugs and other devices.—Dozens of more or less awe-inspiring ore-hunting instruments have been devised and operated by the "experts" who hold the secret of their wondrous powers. These devices, which range from a plain bit of twisted wire to imposing

"radio locators," have been irreverently christened "doodle-bugs" by mining engineers. Ordinarily the operators do not allow their precious gadgets to get out of their hands, preferring to locate rich mines for others on a salary basis.[3]

Many of the doodle-bug experts are exceedingly clever, but they can sometimes be caught if they are willing to undergo rigid tests. One such expert turned up in London several years ago and attracted the interest of important capitalists in a doodle-bug which had the marvelous faculty of smelling out oil, paraffin, and petroleum products of all kinds. A committee of investigators, wishing to test this claim, secreted twenty packages composed of five-gallon cans of kerosene and large boxes of paraffin candles about a large block of office buildings. The doodle-bug was put on the scent, and uncovered every single one of the hidden bundles—a triumph of divination. Unfortunately for the plans of the process-owner, however, a skeptical engineer who was not a member of the committee independently and unknown to anyone hid at the same time ten similar packages in the same locality, and not one of these ten was found! The most charitable explanation is that the owner of the doodle-bug was able to read the mind of some member of the committee.

MINING PHANTOMS AND SWINDLES

Lost mines.—Every mining camp has a host of stories of rich outcrops that have been stumbled upon by chance and have never again been found. In Spanish America there are no doubt many mines which were covered up when the Indians threw off the yoke of their taskmasters, and there are a few well-known cases of rediscovery.[4] The popular belief in the existence of such secrets is traded upon by wildcat promoters, who select for their letterhead some alluring name like "Lost Bullion Spanish Mines Company" and put out a prospectus—largely lifted from the pages of Prescott —to match.

There is no lack of lost-mine stories in the various mining districts of the United States, however, and the mountains and deserts

[3] See "The Prospectors' and Miners' Agency," (edit.) *Min. Sci. Press,* Dec. 4, 1909, p. 741.

[4] See Sheldon, G. L., "Lost Mines," *Engin. Min. Jour.,* April 24, 1915, pp. 746–48.

of the Southwest, according to these yarns, are studded with glittering ledges seen once and never more—but there they lie, awaiting the coming of the true believer with pick in hand. On the Colorado Desert the story is of the "Pegleg Smith" mine, which there is good reason to think started as a newspaper fabrication unalloyed by a trace of truth; yet hundreds of men have believed the circumstantial details of the yarn implicitly, and half a dozen of them have lost their lives in the search for a mine that never existed except in the fancy of a penny-a-line journalist. In Death Valley the stories are likely to be about the "Breyfogle," the "Gunsight," or "Scotty's." On the Mojave River it is the "Lee Mine." Lee was an old, eccentric German prospector who was supposed to have located several native silver outcrops which were never again found; but, curiously enough, one of his prospect holes, which he called his quicksilver mine and to which he attached little value, was "jumped" shortly after Lee was found lying with a bullet-hole in his head, and proved to be a rich silver mine which later produced several millions of dollars.

There is a generic similarity in all such tales, and nothing is lost in the retelling. Mr. Hangdog Jones staggers out of Death Valley into the town of Lone Pine with his clothing in rags and his parched tongue hanging on his chin, clutching in his hand a lump of gold-ribbed quartz the size of a goose egg. When Jones has been brought back to reason by the obvious restoratives he tells of attempting to make "farthest beyond" in the desert, of losing his way, and of burros dying of thirst on a cropping a foot wide and twenty feet long, of which the goose egg is a sample. He is the instant recipient of offers of partnership and loans of cash and equipment, an era of prosperity opens for him as long as he can market his convincing details, and another desert legend is whispered at lonely camp-fires and discussed in offices in large cities. The unvarnished truth of the matter is likely to be that a goodly part of Jones's grubstake consisted of mining-camp whisky, which induced long periods of unconsciousness, during one of which the burros wandered away in search of food and were eaten by coyotes. Their owner was thus forced to concoct an inspired tale to cover his shortcomings and happening to recall that he was carrying about with him a chunk of specimen ore—a relic of "high-grading" at the old Bodie mine—simply decided to use it as a valuable stage property. But by the time his romantic story reaches our ears, the Lost Hangdog Mine will be an outcrop of 14-carat gold a hundred feet wide and a mile long, running right up over the top of a mountain half a mile high. If

one has half a dollar to invest, any of the gentlemen lounging in front of the mining-camp hotel will be glad to divulge its exact location.

Many fortunes have been made from the mineral wealth of the desert, and no doubt a number of good mines still remain to be discovered. But unless he is indeed luck's darling the man who goes out single-handed to find one of the fairy-tale mines will not be the man who discovers these new riches. The mining engineer may well lend an ear to these yarns and, if he exercises a fine discrimination for the more veracious parts of the story, he may even risk ridicule by investigating such tales on the chance that some day one of them may be true. Great discoveries are rare and no opportunity, however slight, to secure a promising mine should be overlooked. Strange things have happened in the quest for mineral wealth, true episodes that put the fictioneering talents of Mr. Hangdog Jones to shame. As one writer notes: "No one of the desert romancers . . . . has yet dared to represent having found anything one-half as good as was discovered during the first year at Goldfield."[5]

Buried treasure.—There must be some obscure reason why the mining engineer is the recipient of all the tales of buried treasure and lost hoards, for persons infected with yarns of this sort too frequently pick him out when attempting to secure money to finance treasure-seeking expeditions. The engineer should regard as hopeless the recovery of legendary buried treasure and secret caches of bullion. The economic geology of such deposits is too complex; they cannot be sampled or measured with any degree of accuracy; working costs are invariably high; many governments impose a special tax upon them in the form of treasure-trove laws: in brief, engineers should advise their clients to forget tales of buried treasure as soon as possible. Although it is true that lost treasure is sometimes recovered and attains a wide notoriety which appeals to the imaginations of all who dream of something for nothing, the business of treasure-hunting involves great risks and lies far from the scientific province of the mining engineer.

Mines that never die.—Mines are catlike in their hold on life, and no one may say that a mine is so dead that it will not be resuscitated and used as the basis of a forlorn hope or fraudulent promotion. A small metal mine in the Lake Superior region was worked for

[5] Storms, W. H., "Legends of the Desert," *Min. Sci. Press*, Dec. 29, 1906, pp. 782–84.

several years at a profit. When operations reached a depth of a thousand feet the vein entered the plutonic rock underlying the whole region, and the value in the ore almost completely disappeared. Moreover, at this point a prodigious flow of water swept into the shaft in such volume that only heroic efforts could check it. Before the management of the company abandoned the property several of the foremost engineers and geologists of the day were called into consultation and gravely pronounced the mine exhausted and unqualifiedly dead. These findings were published far and wide. The works were dismantled, and in time the mine was flooded and there issued from the mouth of the shaft a fine large stream of pure water. Years passed and the stream flowed undiminished. If ever a dead mine could have been expected to remain dead this was certainly that mine; but it was nevertheless used after twenty years as a base of operations for the extensive activities of a gang of swindlers. These men bought the property and gave it a new name. They raked up the dusty records of production, formulated a plausible excuse for shutting down, and evoked a glittering prospect of the profits that could be made under improved transportation conditions and new metallurgical methods. Money poured into the coffers of the fraudulent company, but the mine still yields nothing but water.

Letters to the dead.—Those who believe that the gold-brick game is defunct are evidently unaware of the not infrequent swindle that goes by the name of "letters to the dead." It is worked somewhat in this way. Shortly after the death of a well-to-do man his heirs or executors receive a letter written to him from a far country, addressed to "Dear Henry" and drawn in terms of intimacy and gratitude. The writer, after a few personal details, divulges the wonderful news that he has struck it rich and Henry, who gave him financial assistance when it was badly needed, is now by virtue of his kind deed a half-owner in a rich mine. He is told to come to the mining district secretly and straighten out the business. The credulous heir comes to the mine and is met by one of the swindlers with the depressing news that the adjoining claim must be bought out to retain all rights to the deposit, or with some other equally convincing tale. When the confidence of the victim is engaged by intrusting him with a bag of gilded bars—first fruits of mining operations—he is usually willing to buy out the claims of the swindler's confederate, who promptly decamps with his partner, leaving "Dear Henry's" hopeful heir to lament his credulousness.

FAKE PROCESSES

The man with a secret process is a trial to the engineer. He can, according to his story, manufacture anything from diamonds to India rubber, and can, like Midas, turn everything he touches into pure gold. The "inventor" usually shrouds himself in mystery and is accompanied by a glib manager who seeks the necessary capital to erect a plant and begin production on a large scale. Naturally, the possessor of a secret process is distrustful of divulging any of his revolutionary discoveries; fortunately for him and his schemes, capitalists all too frequently are willing to put their faith and money into his hands without calling in an experienced engineer to pass judgment upon the possibilities of the scheme.

There is ordinarily no reason why a valuable process should remain secret. The patent laws of most countries offer the greatest reward and protection that an inventor could wish for, while the manufacturer who must constantly guard his operations from prying eyes is hampering his interest by taking an unnecessary risk. No matter what precautions are taken, trade secrets have a way of leaking out. The only successful business founded on a secret process was that based on the Bessemer method for the manufacture of bronze powder. The formula was passed on by Sir Henry Bessemer to his son-in-law. The demand for the product was small and all the operations could be carried on by one man.

It is well known that a great part of America's wealth has been derived from industrial inventions, and this knowledge puts the intended victim of this form of fraud into a frame of mind receptive to dreams of fortunes to be made by the introduction of new devices. Science advances at such a pace that it is difficult to say that any particular scheme is categorically impossible, and the fake inventors have a knack of selecting fields of discovery that are fashionable at the moment. The wide employment of such inventions as the airplane, the radio, and television is always attended by a host of allied fake processes and devices.

The main requisite of the fake invention is that it should appeal to the imagination of the victim. It is merely the theme of an elaborate confidence game, which in its highest form approaches the artistry and talent shown in a well-made play. All the best dramatic constituents must be there — setting, "approach," skilful acting, cleverly built situations—but the dénouement too often reveals the triumph of the villainous promoter and the loss of the unwary hero's savings.

The green-gold myth.—One of the most transparent of the fake-process schemes is that which claims to have the secret of obtaining more gold from an ore than is shown to be present by a fire assay. The owner of the secret will expound his theory that gold grows or evolves in the rock and the gold that is extracted by the harsh methods of the assayer represents only that small part of the metal that has reached full ripeness in the course of geological eras. There remains a much larger quantity—perhaps hundreds of times as much—which is in a "green" or immature state but which the wonderful fertilizing effect of his discovery brings to speedy maturity. Of course it would not be safe to patent such an invention, for its application would flood the world with gold and disturb the economic balance; nor would it be safe to intrust the secret to any mortal man. All the faker wants is a guaranteed salary and the erection of works where he can begin turning out gold bars and thus make his backers rich.

Demonstrations by the green-gold man are accomplished through some more or less skilful form of salting. His tale seems so puerile that it would not deceive a child, yet many people have parted with their money to give him a trial. The theme is capable of several variations which ostensibly extract high values from comparatively worthless ore. One Canadian process reported in the mining press is claimed to have yielded $25.65 to the ton from ore that had assayed 70 cents.[6]

Transmutation.—The transmutation of the base metals into gold is a problem that has occupied the minds of men at least as far back as the second century A.D. At that time had begun the work of the alchemists, which was to lead to the modern science of chemistry. For a hundred years or more it has been the fashion to regard their efforts with derision, but recent physio-chemical researches in radio-activity and atomic theory have brought more respect for the alchemist's doctrine that all the metals are formed of one prime material. The possibility of making a small quantity of gold in the laboratory by altering the atomic structure of such elements as mercury, thallium, and lead is no longer remote, but it is extremely unlikely that a successful gold-factory will replace the mine in the near future.

However, the theoretical possibility of transmutation has given a new lease of life to the alchemic quack who possesses the secret of transmuting gold into his own pockets from those of his dupes. As

[6] "The Green Gold Myth," (edit.) *Engin. Min. Jour.*, Feb. 5, 1910, pp. 299–300.

recently as 1931 one of these modern alchemists swindled the German public of a million marks—General Ludendorff was among the victims—and talked of paying the national indemnity by transmuting lead into gold. His demonstration included the application of heat and the introduction of a mysterious powder, which a prominent German chemist assumed to be gold chloride, a compound that when heated will break down and leave a remainder of pure gold. Another ingenious gold-maker was even more recently haled into a San Francisco court, and to substantiate his claims was permitted to display his marvelous art before the astonished eyes of justice.

Synthetic rubber.—The fertility of the fake-process artist's brain is exceeded only by his skill in playing upon the greed and credulity of those with whom he would share the vast profits to be made from his "secret." One of the less usual and obvious schemes was once offered by one of this tribe who claimed to be able to produce india rubber by making use of a certain bacterium which in the course of his biological studies he had discovered. The process consisted of making a gruel of spoiled grain, inoculating it with the secret microbe, setting it out over night in flat pans, and in the morning peeling off a thick slab of pure rubber which needed no refining for the most fastidious market. It was suggested that the exponent of this process prepare the gruel, inoculate it, and permit an engineer to sit beside it throughout the night to await the termination of the cycle that would deposit rubber as its end-product; but such a skeptical proposal was taken as trespassing upon the sanctity of the artist, and the pained promoter betook himself to others, who gave him the financial assistance of which he stood in need.

Steel from sea sand.—The most dangerous of the secret-process vendors is the man who has more than a modicum of scientific training, for he is in position to present plausible technical explanations and it is frequently difficult to expose the particular point at which his theory breaks down. One of this gentry promoted a scheme for manufacturing steel from deposits of black sand on the beach of the Pacific Ocean. One of his victims, in an attempt to recover $65,000 which he had "invested" in the project, arranged to have the claims of the promoter examined by a mining engineer and an expert metallurgist. The promoter was a man of dangerous intelligence, who was fairly well grounded in metallurgy and chemistry. It was pointed out to him that about two-thirds of the black sand deposits was not magnetic iron oxide but tourmaline and other

refractory compounds, and that even the iron portion was contaminated with titanium, which would necessitate the invention of a new process in order to refine it cheaply. He responded by claiming that the deleterious substance was hafnium, an element which had been recently discovered and about which nothing at that time could be proved. Needless to say, it was impossible for the hopeful investor to recover a penny of his money.

The discovery of any new element, it may be said, frequently brings out a crop of fake deposits supposed to contain large quantities of the new metal.

Alum from clay.—An incident involving another process-vendor with fairly good technical training will serve to show how the consulting engineer may have to combat not only the designing promoter but also his credulous victim. This promoter was a chemist with several devices for extracting aluminum and various alum salts from clay. It is true that there is from 25 to 30 per cent of aluminum in many common clays, and the chemistry of extracting it is well known, so that it was not necessary for the promoter to depart far from the truth. His story carried conviction to the engineer's client, who was not easily dissuaded from putting his money into the process. The engineer, perceiving that some spectacular demonstration would be needed and putting his hope in the legal maxim of *falsus in uno, falsus in omnibus,* tried to pin down the promoter to a statement of the cost of producing alum by his process. He finally elicited the admission that by these methods the promoter could produce alum at sixpence a pound. The engineer then marched the pair across the street to a drug store and purchased a pound of alum over the counter for threepence.

Perpetual motion.—An age-old quest that ranks beside those for a universal solvent and the philosopher's stone is that for a machine that will run forever without the application of power. A variation is the attempt to design a machine that will yield more power than is applied to operate it.

Endeavors to increase the efficiency of machines are proper and achievable activities for the engineer, but no engineer needs to be told that perpetual-motion machines that will do useful work are fallacies of the first order. Machines do not create energy, and anyone who claims that they do so denies the law of conservation of matter. A "frictionless" machine, were it possible to invent one, would by that very quality be incapable of application to useful

tasks. The United States Patent Office does not grant applications for patents upon devices on the perpetual-motion principle. Yet the crank inventor is always with us, with a roll of blueprints under his arm and the gleam of the zealot in his eye.

Perpetual-motion machines, many of them displaying amazing ingenuity and commonly designed on the familiar gravity principle, have been used in the past for the purpose of fraudulent promotions. Models apparently in operation may be expected on careful examination to show some form of concealed power. The famous "Keely motor" is thought to have been operated by a hidden series of tubes containing compressed air.

Metals in sea water.—Sea water does contain gold, the amount of which is variously estimated at from five to thirty milligrams per ton. The truth is probably nearer the former figure than the latter; but even at sixteen milligrams per ton the value of the gold will be only about a cent per ton. Even granting such a yield, the cheapest metallurgical methods would almost certainly cost more than the amount recovered. The extraction is not easy.

The form in which gold occurs in sea water is not, as previously supposed, as dissolved aurichloride, but as a mineral slime or as a constituent of the plankton organisms. Its separation is effected quantitatively by adding a minute amount of alkali polysulphide and a trace of copper, and then filtering through fine sand charged with sulphur. This process, however, would not be practicable on an industrial scale.[7]

The fact that there is a trace of the money-metal in the oceans of the globe is seized upon by fake-process promoters who have wonderful machines for rescuing enough gold to pay all the debts of humanity. One of these, after enlarging like his brethren on the inconceivable "reserves" of more than three hundred million cubic miles of ocean water to be worked, confined his chief care to solving the problem of what was to be done with the barren "tailings" after the gold had been extracted. The happy solution he hit upon was a plan to establish his metallurgical plant at the Panama Canal, so that he could draw his "ore" from the Pacific Ocean and use the Atlantic as a dump for the worthless tailings.

Magnesium also exists in sea water to a considerable degree, and recent developments indicate that it can be profitably recovered therefrom. There is also hope that other elemental substances, such as iodine, bromine, chlorine, and others may yield vast stores at a profit.

[7] "Polar Sea Water Comparatively Rich in Gold," *Engin. Min. Jour.*, Dec. 25, 1926, p. 1017.

THEORETICAL PROCESSES

The most insidious sources of loss to those who attempt to develop new processes are those that have a sound theoretical basis but which fail because of flaws encountered in large-scale mechanical application of the principle.

Among these processes may be mentioned three for the separation of lead and zinc: one owned by the British Metals Extraction Company; another, the Ashcroft process, tried out by the Sulphide Corporation; and the De Becci process. Several million dollars were spent by these companies in efforts to apply schemes which were chemically true and exact but which could not be mechanically applied. Others may yet succeed in applying the principle, for theoretically there is no insuperable bar to its profitable use.

Other examples of this expensive class of invention are the Hall sulphur process and the Imbert process for the smelting of zinc sulphides. The Hall process presented at first sight no mechanical or chemical difficulties. It attempted to recover sulphur from iron sulphide not in the customary acid form nor in the form of gas, which kills vegetation and is hard to handle, but in its elemental state. But this state was that of a molecular yellow powder which could not by any devisable means be profitably collected from the air. Some $50,000 was spent in trying to collect this impalpable dust. The Imbert process for the smelting of lead or zinc sulphides appears, on paper at least, to be a chemical miracle whereby the interaction of the constituents supplies more than enough heat to smelt them and in addition furnishes several valuable by-products. The sulphide ore is placed in a closed container, to which is added a portion of molten iron. The theory is that the molten iron will displace the zinc or lead and that from pipes suitably situated the various products may be tapped: metallic lead or zinc, sulphuric acid, and enough reactive heat not only to supply the high temperature necessary to melt the mixture but also to run all the steam boilers in the neighborhood. One of the difficulties is that this reaction is violently explosive and operations must be carried on with due regard for this danger. Much money has been spent in vain attempts to overcome the mechanical difficulties of the process, but it cannot be said with certainty that the problem will always resist solution.

Several processes for the treatment of sulphide ores have been patented which are based on the reactions between sulphides and molten lead chloride. Mechanical obstacles were here encountered

in attempts to handle large quantities of lead chloride in this molten form by pumping it through conduits. In this state the chloride is similar to hot, melted table salt. The chemical process is simple and the reaction well known, but in practice the mixture is found to be corrosive to pumps, and it is almost impossible to keep a large body of it at the proper temperature.

Another group of nearly successful processes are those which were themselves failures but which in the course of experimentation developed methods that later led to highly successful results. The old Elmore bulk-oil concentration process, for example, failed to attain its object economically, but it deserves honorable mention because from it grew the wonderful modern method of concentration by flotation.

A third class of wasteful invention is that which consumes time, money, and skill in the development of highly ingenious devices the applications of which are so limited or the cost of manufacture so great that the market for them is small or non-existent. Many such inventions swell the files of the Patent Office and will never be resurrected because, although technically and practically sound, they are economically unjustifiable.

CHEAP POWER PROJECTS

We are daily surrounded by the surge of vast and inexhaustible sources of elemental power, such as the winds, the beat of the sun's rays, the ever-changing temperatures of water and air, the waves and tides of the ocean, the lightning, volcanic heat from beneath the earth's crust, and the unceasing dance of atoms. With these gigantic reservoirs waiting to be tapped it does seem a pity that we rely mainly upon power from a few windmills, generators erected on a few rivers and waterfalls, and engines run by inefficient combustion of costly fuels; and the inventive mind of man has continually sought for some practicable method of harnessing the great sources of power to his use. So far, little success in these fields has been attained. One of the first difficulties to be encountered in a project of this sort is that the source of power is not in concentrated form; it is, to use a mining metaphor, too "low-grade" for easy utilization. For example, the heat of the sun after it has penetrated the earth's atmosphere is so feeble that in order to concentrate an amount sufficient to boil any large volume of water immense areas would need to be covered by costly collectors of one sort or another. A further

defect of most of these schemes is the intermittent quality of the energy to be utilized. In the example of sun-power just given, the flow of heat is interrupted by the alternations of day and night, winter and summer, sunshine and shower. Until a cheap storage battery is evolved, the cost of holding in reserve a large store of electricity to tide over non-producing periods is prohibitive. One way by which this might be solved is by employment of the suggestion that the intermittent power be used to pump water into a reservoir which would supply a permanent head to operate generators; but obviously such a reservoir, if constructed, could ordinarily be filled by more natural means at a much lower cost.

Solar heat.—There is a legend that Archimedes set fire to the enemy fleet at the siege of Syracuse by focusing the beams of the sun by means of mirrors. The idea of collecting and concentrating the sun's rays for useful purposes has attracted many inventors, the most notable being Erikson, who designed a set of mirrors for generating steam. Not so many years ago a company was formed in South Africa to undertake large-scale smelting and refining by the application of solar heat. The optimism of the promoters of this scheme is revealed by a conservative calculation which indicates that even under the direct sun of the tropics four hundred square yards of collecting surface would be required to heat one ton of charge per hour.[8] The latent heat absorbed in melting would increase the expenditure of heat by another 20 per cent, and no account is taken in these calculations of absorption and dissipation of heat by the collectors and by the atmosphere, nor of the energy required for heating the furnace itself; but the figures are sufficient to show that a large and costly apparatus would be needed to gather the solar heat. This apparatus would need to be movable in order to follow the sun. And not only is the solar energy low-grade but, as has been shown, it is intermittent and therefore undependable.

Power from the ocean.—Various projects have been attempted to utilize the rise and fall of the tides, the restless energy of ocean waves, and the differences in temperature of water at the surface and at the depths.

A small tidal-power machine has been in operation on the Thames near London for a century and a half, and in other places where the tidal rise is great—such as along the Severn estuary in southwest England, the coast of France near Brest, and at Passama-

[8] "Smelting by Solar Heat," (edit.) *Mining Mag.*, March 1910, p. 181.

quoddy on the Bay of Fundy—projects have been attempted for the purpose of impounding, by a series of gates and locks, a large area of water which may be turned to the generation of power. Such schemes are expensive, however—the cost of the Bay of Fundy enterprise was estimated at $100,000,000—and are feasible only in places on the coast where the tides rise ten feet or more. No method has yet been devised whereby the energy caused, for example, by the tidal rise and fall of a 50,000-ton ship alongside its wharf through a distance of four or five feet twice a day could be harnessed and applied to the performance of work.

Many inventors have turned their talents to the discovery of some means of utilizing the vertical motion of an anchored float or buoy rising and falling through the action of ocean waves, but no such wave-motor has ever proved itself an unqualified success. The energy recovered is not great, and much is lost in transmitting the motion to shore. Furthermore, the motion is not steady; the waves may be so gentle that little power is generated, or, on the other hand, a heavy sea may cause too strenuous an agitation and wreck the apparatus.

Another scheme for using waves is by taking advantage of a chamber or cavern in the coast which has its lower part submerged so that, when a wave rolls in, the air in the chamber is compressed and may be run off in a pipe and used for power. Natural chambers of this sort are occasionally found along the coast, and any openings, or "blow-holes," will spout forth a fairly continuous stream of air. But the energy given is insignificant.

More promise for successful conversion of power is held forth in the attempt of Dr. Georges Claude at Matanzas, Cuba, to utilize on a grand scale the difference in temperature at ocean depths and at the surface of the tropic sea. The principle on which his efforts are based is a simple one, and involves the raising of great volumes of water from a depth of more than 3,000 feet, where the temperature is about 41° F. This water would be used in a condensing system that will vaporize, or "boil," the surface water, which at this spot in the Caribbean Sea attains a temperature of 79° to 86° F., thus giving a potential "head" of some 46 degrees. One of the great difficulties, however, is the maintenance of a vacuum necessary to enable vaporization at low temperatures over large boiler areas. There are several other obstacles to the success of the scheme. Eight per cent of the energy generated must be used to rid the condenser of the air and gases exhausted into it with the steam. Additional energy must be

expended in lifting enormous volumes of water from the surface as well as from the depths. Nor is it known how the giant intake pipe, which must be of wood or some similar insulating material, is to be suspended at such depths and protected from incrustation and destruction by the marine growths that infest tropic waters.

The answer of Dr. Claude to all these doubts is that sea-power plants must be gigantic in size, capable of producing some 300,000 horsepower. The cost of erecting such a plant, he estimates after spending about a million dollars on the Matanzas project, would be some three or four millions. It is yet to be seen whether such a tropical power-plant can be made mechanically and economically feasible.

Atomic power.—The unceasing dance of the atoms seems a more fertile field than the others. At this writing, atoms have been controlled to produce explosions of a terrorizing violence and effectiveness. Whether methods will be discovered which will produce a flow of energy with which we can live remains to be seen. If this peacetime utilization can be accomplished, at a cost which now it seems will be but a trifle per unit, there might open for the human race an era of unparalleled magnificence. Such a flow of atomic energy might also contain the germs of methods of reducing the present wasteful use of minerals and so prolong the life of the world's mineral reserves.

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Chapter 19

The Mining Engineer and the Law

The mining and metallurgical engineer will, in the course of his professional experience, come in contact with many legal problems. Although he cannot be expected to have a knowledge of law that will enable him to act at all times as his own legal representative, a practical understanding of certain principles of law will serve as a sort of "first aid" in emergencies when he must act without consulting a lawyer, and will also help him to co-operate intelligently with his legal advisers. He should seek the assistance of a competent lawyer in every case where there is the slightest doubt of his position or the position of his employer; and any business enterprise of importance should retain the counsel of an attorney on an annual fee.

There is one principle that the engineer should always remember: Avoid litigation by every honorable means. An eminent British solicitor was asked by a friend for his opinion on the advisability of bringing suit against a business foe. "Well," said the solicitor, "if a stranger should come into my office and forcibly eject me, I should probably sue him—but I think I should be wrong in doing it."

One is sometimes forced into a lawsuit and is always obliged to comply with legal statutes, and the engineer will find it useful to make an effort, during his college course or afterward, to obtain practical knowledge of certain branches of law. He should know something of the common law, the crystallization of customary usages between man and man. He should also have an understanding of the civil law, which grows from Roman origins and is the foundation on which are based the laws of the Latin countries, where legal rights are viewed from a standpoint quite different from that prevailing in the English-speaking world. As a business man, the engineer will be required to practice the customary methods of doing business, making contracts, and acting as an agent. He must have some comprehension of the laws of property, rents, and leases, and, when dealing with labor, the statutes regarding claims, damages, compensation, injunctions, labor laws, and criminal acts. Financial

rights and liabilities are dealt with in the body of corporation law, tax laws, and in the laws designed to protect investors against fraud. Finally, he should certainly have a working knowledge of the statutes under which mining rights are secured and held.

Although the law enters into the engineer's activities most prominently during the period of organization, and hence is properly dealt with in the present section, it should be noted that certain branches of the law apply more closely to the valuation or management of a mining enterprise, for it is a not inconsiderable part of the duty of a manager or valuing engineer to make sure that the title to the property held by his employers is clear. Corporation law applies not only to the organization of a company but also to the operation and administration of the company. The laws governing taxation may in some districts be a factor limiting the success of a proposed venture, and likewise constitute a problem ever confronting the management of an operating company. And at every stage of commercial activity business law must be consulted.

It is obvious that in a single chapter no great attention can be given to the tremendous body of law that may affect the mining engineer. All that can here be attempted is to make a few general observations on the subject, to list the branches of law that will be of acute interest to the engineer, and to refer him to his legal adviser and to the bibliography at the end of this chapter if he wishes to pursue his study beyond a mere outline.

BUSINESS LAW

American business law is a body of customary usages which has developed from the common law through recognition by legislation and judicial decisions. These usages govern the dealings between one individual and another and define the rights and privileges of each with regard to ownership, contracts and other instruments, injuries, agency, selling, and the like.

Agency.—There is much popular misunderstanding of the duties of a principal toward his agent and the extent to which an agent—in which capacity the engineer often acts—can bind his employer.[1]

A principal owes three main duties to his agent:

1. To compensate him in accordance with the terms of their contract; or, if no contract is made, to pay him a reasonable compensation for his services.

[1] See Frey, A. B., *American Business Law*, p. 207.

2. To reimburse him for his advances and expenses properly and reasonably incurred for and on behalf of his principal.

3. To repay him any damages which he was compelled to pay because of acting, at the direction of the principal, in a manner not manifestly illegal or known by the agent to be illegal. Such payment is called indemnity.

An agent owes six main duties to his principal:

1. He must obediently carry out the directions of the principal so long as they do not require that he violate the law.

2. He must use the utmost good faith toward his principal. An agent must be careful not to place himself in a position where his own interest will come into conflict with that of his employer.

3. He must possess and exercise the skill and diligence which he has represented himself as possessing.

4. He must keep and render faithful and accurate accounts of all property coming to him in the course of his agency. He must keep the funds of his principal separate from his own.

5. He must give timely notice to his principal of all facts coming to his knowledge, a reasonable time before, or at any time during the period of his service, which relate to the subject-matter of the agency, if such facts are necessary for the principal to know in order to safeguard his interest.

6. He must act in person. He cannot delegate to another person the performance of any duty requiring discretion unless his principal has expressly or implicitly authorized him to do so, although he may delegate the performance of purely mechanical acts.

Contracts.—A contract has been defined as "a bargain or agreement voluntarily made upon good consideration, between two or more persons capable of contracting to do, or forbearing to do, some lawful act." The four main qualities which are needed to make a valid contract are thus: (1) agreement, (2) exchange of valuable consideration, (3) competence of contracting parties, and (4) legality of object.

The offer upon which the parties agree must be certain and unambiguous and can be accepted only by the person to whom it is made. It can be withdrawn at any time before acceptance. An offer sent by mail or telegraph is of no effect until it reaches the person to whom it is offered. The acceptance of an offer becomes a contract the moment it is mailed or a prepaid telegram is given to the telegraph company; the fact that acceptance is not received by the offerer has no effect.

Consideration is necessary to the validity of every contract. The exchange of a consideration in return for a promise shows that the agreement was not made gratuitously. There is sufficient consideration if any benefit is bestowed on the acceptor or any loss is undergone by the offerer. A promise to do what the promiser is legally bound to do otherwise is not a consideration.

Those incompetent to make contracts include those declared by law to be incompetent (such as insane persons or spendthrifts) and alien enemies. State laws differ regarding the competence of minors, aliens, and married women, although these persons have in most states the right to make valid contracts. Agreements entered into under duress or undue influence are voidable at option. Corporations are allowed to enter into contracts within the limits of their corporate powers; if a corporation makes a contract which exceeds these powers it is said to be *ultra vires* and is void.

Agreements in violation of positive law, or to commit a fraud, or which are opposed to public policy, or in restraint of trade, are unlawful.

Written agreements are not voidable on the grounds that the signer did not read the contract or did not know its contents.

Contracts are discharged by performance, by mutual agreement, by breach of contract, by operation of law (bankruptcy, alteration of written agreement, or merger), and by impossibility of performance.

The first thing an engineer does when accepting a position is to enter into a contract for his employment. If he is not certain that the contract is in accordance with his understanding of the conditions, and that it will insure him fair and just treatment, he should submit the written agreement to a lawyer or other competent person and obtain his opinion. In many contracts for employment there is some such clause as: "The party of the second part hereby agrees not to disclose, either during the course of his employment or after, any material information which he may obtain concerning the company's operations." It has been held by courts that such a contract is not binding on the signer *after* the contract has been discharged, at which time the former employee may be required, as a witness in a court of law, to give evidence concerning information which he obtained during the period of his former employment.

Other business instruments. — A "negotiable" instrument is a form of contract which presumes that a consideration has been

received, and which is negotiable, i.e., the legal title to the instrument, and the whole amount of money expressed on its face, may be transferred from one person to another by indorsement and delivery, or by delivery only. The most important classes of negotiable instruments are promissory notes and bills of exchange (which include checks). Under the Uniform Negotiable Instruments Law, an instrument, to be negotiable, must be in writing and signed by the maker or drawer, and contain a promise to pay, to order or to bearer, on demand or at a fixed future time, a certain sum of money. Where the instrument is addressed to a drawee, he must be named or otherwise indicated therein with reasonable certainty.

The quality of negotiability, however, is not merely transferability, but the fact that a third party to whom the instrument is transferred may get rights that the original holder did not have. Unlike an assignee under an ordinary contract, an innocent transferee who takes a negotiable instrument in the course of business may sue for payment on it when due, in his own name, and is entitled to receive payment regardless of any reason for non-payment that might exist between the original parties. If the law of negotiable instruments had not grown up, no one would dare discount a note for fear that some reason for non-payment, unknown to the assignee, would destroy the whole value of the note when due.

A check is a bill of exchange drawn on a bank, payable on demand. It must be presented within a reasonable time after its issue. A certified check is equivalent to an acceptance by the bank on which it is drawn, and discharges the drawer and all indorsers from liability thereon.

Contracts of suretyship and guaranty must be in writing to be valid. A guarantor undertakes to perform a contract or obligation which *cannot* be performed by the person guaranteed. Suretyship is a direct contract to pay a debt or to perform some act or duty which the principal *does not* perform; a surety is immediately liable as much as his principal as soon as default is made, and suretyship is much more stringent than guaranty.

An engineer should retain carbon copies of all important business correspondence. Carbon copies of letters and other documents are admitted as legal evidence, and they are also valuable, naturally, as records for the information of the writer himself. Photostat copies of documents are also admitted as evidence in court.

Claims and damages.—The legal principle regarding claims and damages is that an obligation violated must be one owed to the party

claiming to be injured, and that there is no right to damages where no wrong has been committed.

Damage suits for accidents are unavoidable, some involving fictitious, exaggerated, or real injuries. Where the company is operating smelting furnaces, which yield noxious gases, damages to land or stock may be claimed on this account also. Companies receive and dispatch a large amount of ore, products and supplies by rail, and since railroads insure the freight, they are called upon to pay claims for damages, where accidents, and especially fires, give rise to such claims. The injury or delay of materials in transit may also be productive of claims of the company against the railroad; such claims when they cannot be adjusted peaceably, ultimately give rise to suits, but even before a suit is brought, legal advice is necessary in the process of adjustment. The company may be harassed by garnishment of the wages of its employees and the danger of double payment must be guarded against. The arrest of wrongdoers has to be made under legal advice, as upon failure of any criminal proceeding, a suit against the company for malicious prosecution may be expected. . . . . If anyone is injured or killed it is the business of the lawyer to reach the spot promptly and endeavor to settle claims without delay. Even a small delay involves having to pay the claimant's lawyer as well as himself. The statements of witnesses are to be taken down in writing, both for enlisting the witness on behalf of the company, and for recording the facts before they are forgotten. The importance of such work is seldom appreciated, but as a rough estimate, it is about three times as expensive to dispose of a claim by litigation as by amicable settlement. The effort to settle should be continuous, instead of being dropped until suit is brought.[2]

LAWS RELATING TO EMPLOYMENT OF LABOR

Aside from the laws of contract, agency, and damages, there are certain phases of legislation designed to govern the relations between employer and employed, and several other phases of law with which those in charge of workmen will come in contact. It is especially desirable that a mine manager should know the terms of these laws and his powers of action, for many times the need for their application is in an emergency, when a lawyer cannot be consulted, and the manager through ignorance might implicate his employer in litigation that would arouse considerable ill feeling.

The mine manager should of course be familiar with prevailing laws regulating wages, hours of work, working conditions, and labor performed by women and minors. These subjects will be mentioned in a later chapter.

[2] "The Legal Work of a Mining and Reduction Company," (edit.) *Min. Sci. Press,* June 15, 1907, p. 763.

Protection of property.—A mine or metallurgical plant constitutes a large outlay of capital, and it is the duty of the manager to endeavor in all possible ways to protect this property from damage or destruction by harmful or criminal acts. If a wrong is committed by a party who is able to pay damages it is possible to enter a lawsuit against him. However, if there is a reasonable fear that a wrong may be committed by an insolvent person, or one who would not be able to pay for the damage he might do, it is possible to go into a court of equity and obtain an injunction restraining him from committing a certain harmful act. To violate this injunction would be in contempt of court and the violator would be liable to punishment.

It is likely that the appeal to injunction has been abused by some mine operators in the past, or has been unnecessarily invoked, thus causing ill will among workers. Such steps, however, are the only protection a property owner may legally use to prevent the destruction of his capital by acts of violence committed by agitators and dissatisfied workers who are financially irresponsible.

Workmen's compensation laws.—The state laws which have been instituted in the last few years to compensate workmen for injuries sustained during the performance of their duties are virtually a form of insurance, the premium on which the employer is compelled to pay. Since mine workers are classed as high risks and the premiums are accordingly large, the expense will ordinarily constitute a considerable item of operating cost; and, indeed, in some countries and some states the compensation rates may make all the difference between success or failure of a projected mining enterprise.

In one Western state the compensation premium for mine workers is higher than the rate for almost any other occupation. Careful studies show that the larger and better-organized mines do not present a very great hazard; the accident rate for the industry as a whole is in very great part a result of carelessness and inefficiency obtaining at small mines where adequate protection is not afforded. Such laws, it is believed, discriminate against the large operator, for he not only expends much money on protective devices and safety-first campaigns and thus lowers the risk rate for his own force but he must also bear the cost of insuring workers in more hazardous mines over which he has no control.

The employer is forced to bear the whole cost of compensation insurance, and political forces have worked to increase systematically the indemnities paid and hence to raise premium rates. The

employer is unable, under competition, to pass on the increased cost by raising prices, and therefore must resort to rigid medical inspection and restriction of employment through enforcing stricter age limits and turning off applicants whose general health or capacities are poor. Employer responsibility for any accident or disability—even for injuries occurring beyond his jurisdiction—is almost unlimited. All these hardships discourage prospecting and the starting of new businesses, and such paternalistic legislation will in the end do harm to labor by increasing unemployment. It is obvious that the cost of insurance should be divided between employer and employee.

LAWS OF CORPORATIONS AND PARTNERSHIPS

The legal requirements for the organization of business units have been broadly discussed in earlier chapters which deal variously with the creation of partnerships and corporations, the advantages and limitations of these forms of business units, types of corporation, the powers of a corporation and its obligations to the state and to the stockholders, the forms of securities issued by a corporation, limitation of liability, and laws aiming to offer protection to investors. Action at all these points should be governed by the advice of a capable corporation lawyer.

It should be noted that from a legal point of view a corporation is an "artificial person" created by law for specific purposes, the limits of whose existence, powers, and liberties are fixed by its charter. It is a legal entity distinct from its members, and as such can hold property, contract, and sue. When the life of the corporation is not limited by its charter or by statute, it has perpetual succession. It may be dissolved by voluntary action, expiration of charter, misuse or non-use of corporate power, or bankruptcy.

AMERICAN MINING LAW

The system commonly referred to as American mining law is a body of court and Land Department decisions based on a comparatively small number of federal statutes and statutes of certain Western states. These laws are not ancient; the first federal act was passed in 1866 to establish certain general principles that rose out of the helter-skelter location of claims under the local rules of Western mining districts in the 'fifties and 'sixties. These local regulations were based on the most primitive and conflicting ideas of right and justice, mingling concepts taken from Anglo-Saxon com-

mon law and Mexican, Cornish, and European practice. The haphazard growth of American mining law has led to a number of illogical and complex interpretations which have in the past occasioned much litigation, especially those relating to so-called "extralateral rights."

Mining laws are made primarily to regulate the acquisition and possession of the right to exploit a mineral deposit. "These laws define the status of the prospector for mineral deposits, establish his methods of procedure, protect him in possession while searching for mines, and give him assurance of title when all required conditions have been fulfilled and valuable minerals discovered."[3] In return for title to a mining property under the legal conditions laid down, the owner is expected to pay certain taxes, royalties, or rents to the state or other landlord, and to take action to perform a reasonable amount of work on the property so that the capital represented will not stand idle.

Concession vs. claim system.—The mining laws of the world are based on two principles, one relating to "concessions," the other to "claims."

1. *The concession system.* Under this system the state or the private owner has the right to grant concessions or leases to mine operators at discretion and subject to certain general restrictions. It had its origin in the ancient regalian doctrine that all mineral wealth was the prerogative of the crown or the feudatory lord and obtains in almost every mining country in the world except the United States. More than five-sixths of the mining areas of the world, it is said, are worked under concessions; the British South Africa Company, for instance, controls 440,000 square miles of territory under a Crown concession. In general, it may be said that the system, although capable of abuse and tending toward placing the privilege of mining in the hands of a few individuals, is more economical than the "claim" system.

2. *The claim system.* This system grew up in the early days of mining in Western United States, following the gold rush of 1849, as an outgrowth of the desire of the prospector to develop a mineral deposit discovered on the public lands and to have his claim confirmed by law. Although at first sight the system may appear to encourage individual enterprise, it often leads to a great waste of capital and energy, and the complexity of doubtful cases arising

[3] Peele, Robert, *Mining Engineers' Handbook*, 2d ed., p. 1654.

under the American mining laws regarding claims has erected a pyramid of litigation that has heavily burdened the mining industry.

Origin of American mining law.—In order to understand how the illogical and needlessly complex claim system has become established in the United States, it is necessary to make a brief historical survey of federal policy regarding the allotting of parts of the public domain to citizens.

The federal government acquired no property rights within the boundaries of the thirteen original states or the four other Eastern states, and the first acquisitions came through cessions, by seven of these states, comprising territory lying east of the Mississippi River. Later acquisitions from France, Spain, and Mexico extended the boundaries of the nation to the Pacific Coast and added a tremendous area to the public domain. The purchase or cession of territories such as Alaska, the Hawaiian Islands, Porto Rico, and the Philippines did not, however, add to this domain, for previous laws in these territories were ordinarily maintained or special laws for them were passed, and federal statutes regarding public domain do not therefore apply to all the territory controlled by the United States.

Since nearly all the lands that did pass under federal statute were acquired from France and Mexico—both of which countries had well-established mining codes under civil law—the influence of the regalian doctrine which was paramount in these countries has been in conflict with the Anglo-Saxon common-law principles that grew up in the United States and confirmed the right of a landowner to the minerals beneath the surface. The regalian doctrine did not prevail, and therefore a patent from the federal government has ordinarily carried with it the right both to hold the surface of the property and to mine all minerals beneath the surface. Title vests in the patentee absolutely, and under most conditions the land becomes private property, subject to the laws governing other real property. Mining claims cannot be located on private property in the United States, as may happen in many countries of Europe and Latin America, where the concept prevails that mineral wealth pertains to the Crown and is not comprised in surface ownership.

From 1807 to 1847 Congress leased mineral lands, but the results were unsatisfactory and the system was abandoned. When miners from all parts of the world flocked to the Pacific Coast the mineral lands were unsurveyed and there was no federal administration or restriction of mining in the public domain. Regulations were worked out by small groups of miners in the various districts. These

men, ignorant of precedents and principles, met together and passed rules which were the outgrowth of the needs of the hour in rude times and were based merely upon expediency. These early codes have been termed by R. W. Raymond, a writer of greatest authority, the "law of the lariat."

> With the lariat they measured the distance assigned to each miner along the gold-bearing gulch—a double portion to the discoverer, and a single portion to his successors, in the order of their coming. With the lariat, they hung, after such due process of law as was available, the rascal who stole a horse, or a bag of gold-dust, or a mining claim, or killed another man without giving him a fair notice and a chance to defend himself.[4]

These early miners in California, with an imperfect knowledge of law and history, but with a strong sense of justice, keenly felt that the labor and pains of discovering a gold deposit should be generously rewarded. They therefore gave priority to the discoverer, and allowed him a double "claim" along the gulch. The claims were measured in one dimension only: "so many feet of the gulch, held by one man, meant a distance into either bank, and a distance in depth, extending as far as gold might be found." Raymond continues:

> Meanwhile, in many districts, the discovery of metal-bearing veins had inaugurated the new industry of "quartz-mining," and the pioneers simply applied to these deposits the rule already adopted for gold-bearing gulches: namely, they treated a vein as if it were a gulch; granted mining claims upon it, measured by a single dimension, and included in each claim all "dips, spurs, and angles," i.e., all valuable mineral branching from the main vein between the two ends of the claim.

This casual state of affairs led to an almost limitless number of disputable cases, for when a locator follows all the ramifications of the portion of the lode assigned to him it is to be expected that he will sooner or later come into conflict with owners of neighboring claims. That this system, termed the "law of the apex" or "extralateral right," is a much more complicated and impractical basis for a precise mining code than the system based on "vertical boundaries" will become clear in the course of the discussion.

The four main ideas—discovery right, appropriation by the individual, need for development to establish a claim, and equal opportunity for all seekers—run through all these local codes. The similarity may be easily explained by the fact that miners continually shifted from camp to camp throughout the gold districts.

[4] Raymond, R. W., "Comparison of Mining Conditions Today with Those of 1872," *Trans. A. I. Min. E.*, Vol. 48 (1915), p. 299.

The "law of the lariat" altogether ignored the rights of the federal government as owner of the land, and the Act of 1866 attempted to legalize the conditions that had grown up previous to that time. It stated that all mineral lands in the public domain should be free and open to exploration and occupation, and that rights acquired under local regulations should be recognized and confirmed. In 1870 an amending and supplementing act made placer claims also patentable, including with placer claims all deposits not lodes. The Act of 1872 remedied a defect of the first act by granting ownership of the surface to the locator. As Raymond states:

> The Act of 1872 was revolutionary. It made the mining right an appurtenance to the surface location, instead of granting an easement in the surface as an appurtenance of the mining right; for the reward of the discoverer it substituted the luck of the apex-possessor; and the title conveyed under it was subject to doubt and possible defeat as the consequence of new geological discoveries so long as the mining ground which it was supposed to cover might continue to be worked.[5]

This act, termed by Raymond the "law of the apex," is in the main the law under which mining rights in the public domain have been acquired up to the present day, and this opportunist legislation has led to almost endless litigation concerning "extra-lateral rights."

Vertical boundaries vs. extra-lateral rights.—It seems likely that the earliest miners, such as the Phoenicians, followed the pay streak wherever it led, without much regard for surface rights. Boundaries of mining properties at the ancient Greek lead-silver mines of Laurion, however, are known to have been vertical (that is, the right to mine did not extend to underground parts not directly under the surface of the property); but this was almost inevitable because the Laurion ore deposit was a flat bed. Vertical side-lines were in all probability early applied to inclined deposits, judging from a Roman law in force in Spain, where the discoverer was allowed to move his side-lines a certain number of feet for each degree of dip, so as to include the extension in depth of an inclined vein. In medieval and modern times these two distinct concepts govern the right to mine underground deposits: the concept of vertical side-lines allows the miner to work the ore within the limits formed by planes vertical to the surface boundaries, while that of "extra-lateral right" gives him the privilege of following his vein on its downward course, even if it dips beneath the surface of an adjoining claim. Obviously, the

[5] Raymond, *op. cit.*, p. 302.

simplicity of the vertical side-line law makes it easy to apply; while, on the other hand, under extra-lateral right there may be as many causes for dispute as there are differences in the geology of veins.

The principle of vertical side-lines, which may be termed the Roman system, prevails in the mining laws of virtually every country except the United States, where the extra-lateral right—which was tried and abandoned by the Germans in the sixteenth and seventeenth centuries—has grown out of the local rules of Western gold-miners. Although the "law of the apex" has given employment to hundreds of legal gentlemen and expert witnesses during the past sixty years, and volumes of opinions on its interpretation have been printed, there still exist a number of vitally important cases under the law on which the courts are not agreed and which may lead to the loss of titles under which certain mining companies operate. That many trouble-breeding points in the statutes are still unsettled even at this late day is shown by the fact that there is even now considerable agitation among mining men for the revision of this perplexing law. It is worthy of remark that extra-lateral right may be legally nullified by agreements among title-holders in a certain district. This has been done in some of the copper-mining regions, and general satisfaction has resulted from the adoption of vertical boundaries.

Mining rights in the United States.—The following summary gives the requirements under which mining rights are acquired and held under federal law. The laws of the various mining states, which do not differ greatly from the federal law, are summarized in Peele's *Handbook,* pages 1669–82.

The possession of mining rights is conditional upon *discovery* and *development.* Discovery has been defined as

> knowledge of the presence of the precious metals within the lines of the location or in such proximity thereto as to justify a reasonable belief in their existence. But in all cases there must be a discovery of mineral, in both lode and placer claims, as distinguished from mere indications of mineral.[6]

A certain amount of preliminary *development work* is essential to the completion of a location (fixed by national law at $500 worth) and, in addition, an amount of *labor and improvement* (fixed by national law at $100 worth annually) is required in order to maintain title.

Posting of notice is not required by federal law, but is com-

[6] Ricketts, A. H., *American Mining Law,* p. 338.

pulsory under the laws of almost all of the mining states, which stipulate the manner of posting. Description of the location should be referred to some permanent monument or landmark the direction and distance of which must be stated with reasonable accuracy—although, of course, the accuracy of a detailed survey is not expected.

The federal statute does require that the location be *marked* so that the boundaries of the claim may be traced by a person of average intelligence, using the location notice as a guide. Effacement or destruction of marks by another person does not invalidate the claim, but the marks should be replaced in as permanent a manner as possible.

Recording notice of location is not demanded by national law, but nevertheless, it specifies the content of the record. It is required by the majority of the states, which allow time to record locations varying from thirty days after date of discovery to ninety days after location. Failure to record within the time limit will invalidate the claim, and it is therefore dangerous to procrastinate.

The claim to a title gains in strength as each step in obtaining a patent is taken without contest. The recorded notice of a location, in the absence of a prior record, is valuable evidence of discovery, marking, and posting; a locator filing such a notice is assumed to be in possession, and the burden of proof as to invalidity is upon the contestant. The recording of notice of location often serves the useful purpose of evincing relations between partners; a prospector working on grubstake, for instance, should always include the name of his backer as one of the original locators.

The maximum *size of a claim* under the federal statute is 1,500 feet along the vein or lode discovered, and 300 feet on each side of the middle of the vein at the surface. Any area in excess of this should be cut down when the claim is surveyed during patent proceedings. If the vein is extremely crooked, complications may arise; in such a case it is safer to locate several claims to cover the course of the vein. The end-lines of the claim (which are two lines laid crosswise of the vein at the surface) must be parallel. Any mistake in this particular should be corrected at the earliest possible time, for parallelism of end-lines is the very essence of the law of the apex, the theory of which is that the mining rights follow the dip of the vein lying within the end-lines.

When improvements to the amount of $500 have been made on a claim, and an affidavit has been filed in the record office, a patent

may be applied for. The improvement work must be done for the purpose of developing the property and extracting minerals, and labor should be employed for sinking a shaft or driving an adit; it does not suffice to saw lumber, to start farming, or to build a summer home in the mountains. The only safe way in which to comply with this requirement is by doing the work in good faith with the intention of developing the claim; if the property is not worth this required expenditure, it is not worth patenting at all.

A *patent*, which is the deed or grant of the United States given through the Land Department and conveying legal title to a certain location, is obtained by applying to the United States surveyor general of the district for a survey of the land to be made by a United States deputy surveyor named by the applicant. A copy of the location notice for each location to be included in the survey must also be filed, and a deposit must be paid to cover government fees. The cost of the survey is additional to this and is paid directly to the deputy surveyor named. This official then makes a survey of the claim and reports on the amount of work done. His report, if it is in order, is approved by the surveyor general, and copies are forwarded to the applicant, one copy to post in a conspicuous place on the claim in the presence of two witnesses, and one copy to file in the local land office. The register of the land office then publishes, for a period of sixty days in the newspaper nearest the claim, a notice describing the claim and stating that application has been made. If at the end of sixty days no adverse claim has been filed with the land office, it is assumed that the applicant is entitled to a patent, upon payment of five dollars an acre.

The file of *documents* required for the obtaining of a patent include the following: (1) application, (2) affidavit of posting, (3) affidavit that all requirements for application have been fulfilled, (4) evidence of citizenship of applicant, (5) power of attorney, (6) copy of survey, (7) certified copy of location notice and abstract of title, (8) agreement of newspaper owner to look to applicant for cost of publication, (9) notice for publication, (10) affidavit of publisher testifying to publication, (11) affidavit of claimant that notice has been posted (two witnesses), (12) affidavit of claimant that fees have been paid, and (13) written application to purchase property at five dollars an acre.

Mining rights may be *forfeited* by failure to comply with the law, or by abandonment. Since abandonment is a matter of intention, and since common-law concepts work to protect a locator who

makes even the feeblest attempt to comply with the letter of the statute, government claims are not easily forfeitable.

Even prolonged abandonment followed by peaceful possession by others does not remove the blot so that a title may be considered secure from attack. The safe course is to bring action against the former claimant for quieting title. Abandonment is not easy to prove and a man's title to a mining claim endures indefinitely, though he perform no annual work upon it, until adverse possession has been made effective, and even then, if he choose to contest possession with the new locator, the burden of proof of abandonment lies upon him who would assert adverse rights.[7]

Patent to a *lode claim* conveys (1) right to all surface land comprised in the location, and (2) right to all veins, lodes, and ledges, throughout their entire depth, whose apexes lie within the boundaries of the location. The right to pursue the vein beyond the boundaries is subject to certain limitations. The boundaries of the patent may be invaded by a neighboring lode locator following his vein on its downward course beneath the patented surface; i.e., the law of the apex obtains. Patent to a *placer claim* conveys to the holder everything within the vertical boundaries of the claim except lodes whose apexes are within these boundaries and whose existence was previously known, and except portions of a lode underlying the placer surface which may be pursued by a neighboring lode locator lawfully following his vein on its downward course.

Water rights.—A supply of water is almost as important to a mining enterprise as a supply of ore, and this was recognized by the federal statute, which confirmed the existing water rights of holders under local laws and gave right of way over the public lands for ditches and canals used in appropriating and applying waters for mining purposes, but allowed the right of settlers on these lands to be recompensed for any damage resulting from the construction of such ditches and canals.

The law under which water may be appropriated in the Western United States is too complicated to describe in detail, but in general the following procedure is required: If a stream of water has not been previously appropriated, a notice of appropriation should be posted along it, stating definitely the use to which it will be put. The second step is to be reasonably diligent in the diversion of the water for the purpose specified. The third step is to apply the water usefully. Use must be continuous, for water rights lapse with discontinuous

[7] De Kalb, Courtenay, "What Should an Engineer Know of Law?" *Min. World*, Jan. 8, 1910, p. 56.

use. Water cannot be appropriated if the prior right of another has been confirmed. Diverted waters must be used without unreasonable pollution or contamination; but the exact interpretation of the term "pollution" is a matter for a jury to decide in a suit for damages.

A prior locator cannot insist that the stream above him shall not be used by subsequent locators or appropriators for mining purposes and that the water shall flow to his claim in a state of absolute purity. While the subsequent locator will not be permitted to so conduct his operations as to unreasonably interfere with the fair enjoyment of the stream by a prior locator, or to destroy or substantially injure the latter's superior rights as a prior locator, nevertheless the law recognizes the necessity for some deterioration. . . . . Any other rule might involve an absolute prohibition of the use of all water of a stream above a prior location in order to preserve the quality of a small portion taken therefrom.[8]

Any use of a stream that materially fouls and adulterates the water and impairs it for the ordinary purposes of life will constitute a nuisance, and anyone damaged may take the case into court.

Forms and titles.—The engineer should have more than a smattering of knowledge concerning the legal instruments used to conform to mining law. Although he cannot be expected to make a judgment upon the validity of the titles upon which possession of a property rests, he should have an understanding of legal documents such as deeds, mining leases, working bonds, notice of right to water, and escrow agreement. Forms for these documents may be found in Peele's *Handbook,* 2d ed., pages 1710–12.

Almost all mine examinations and sales of mines are conducted under some form of option. Since it has been ruled, in cases wherein a seller has refused to carry out the terms of an ordinary option, that the prospective purchaser's only redress was in an action for damages, mining engineers and mine-buyers should beware of options. It is preferable to put the agreed terms in the form of a lease, or better, in the form of a working-title bond, accompanied by the deposit of deeds to the property in escrow in a bank. Then, if the purchaser performs the acts incumbent on him, the holder of the deeds in escrow hands over the title to the purchaser without the necessity of consulting the seller. Such contracts as working bonds should, of course, be validated by the acceptance of an adequate consideration.

Mining law of other countries.—The engineer accustomed to the mining laws of the United States will find himself in a new world

[8] Ricketts, A. H., *American Mining Law,* p. 93.

of legal theory when he is engaged to do business in foreign countries. He will then need to acquire some understanding of Roman civil law, regalian right, the concession system, vertical boundaries, and mining legislation peculiar to the national needs and concepts of equity. It is impossible here to mention the differences in law to be found in the more important mining countries of the world aside from the United States. Reference is made to the series of information circulars of the United States Bureau of Mines, which give synopses of mining law in almost all of the mining countries of the globe.

FEDERAL INCOME TAX LAWS

Equitable taxation of industry is one of the knottiest problems confronting legislators, and the history of the federal taxation of mines reveals that for many years Congress and the Treasury Department have been groping toward a saner policy of levying taxes on this basic industry. Although no simple and absolutely just theory of mine taxation has yet emerged, it is becoming more widely recognized that the conditions under which the mining industry produces wealth differ radically from those applying to the manufacturing industries that depend upon mining for many of their raw materials. Some of these conditions which have caused taxation dilemmas will be mentioned here, in order to show that there is no simple path to establishing a tax policy that will lay an equitable burden on every mineral producer.

In the first place, it may be argued with some reason that the mining industry should not be taxed at all. It has been pointed out that the health of our industrial civilization depends upon the annual production of millions of tons of metals, coal, petroleum, and other minerals, and that if the production of these raw materials is curtailed every other commercial activity will suffer. Most of the great nations explicitly recognize that mining enterprise should be fostered and encouraged in every way. In the United States this truth has been given due regard by legislators in times of war, when the strategic importance of an unfailing supply of mineral products is urgent, as witnessed by the rewards given to initiative by the tax laws of 1918. But in peace times the mining industry has been left to fend for itself or, worse yet, has been unthinkingly classed as "big business" and taxed on the belief that all mine operators are members of the predatory rich. Although it is true that some indi-

viduals receive large profits from mining, the industry as a whole is a hazardous one and most mining ventures are losses. The metal supply is today being maintained by working ores of decreasing value and of increasingly difficult and costly metallurgical treatment; and it cannot long be maintained at its present rate of production unless the economic system encourages the hazardous enterprise of mining by holding forth the lure of profits commensurate with the risks incurred. Were the government to take the lion's share of whatever profits are made by mining, the risking of capital in discovering and opening new mines would suddenly come to a halt (as it has in those countries that have taxed to death all mining initiative); and the effect upon the nation's industry would be fatal.

Patient and open-minded co-operation between government agencies and the spokesmen of the mining industry, however, has averted any such disastrous outcome, and compromises have led to the adjustment of those parts of the national tax laws that worked grievous hardship on many mining companies in the past, although not all injustices have yet been relieved. It should also be remembered that in the United States there are, in addition to the federal government, also state, county, and local taxation powers that in many cases bear heavily upon mining initiative and that operate on taxation theories which many times fail to recognize the peculiar conditions under which the minerals of the earth are converted into wealth.

Assuming, however, that the mining industry should bear a part of the expense of government, since it enjoys the protection and benefits deriving from the state, what is a just basis on which such a tax should be imposed? It is not easy to set up a simple standard that may be applicable, without exception, to all cases. Two taxation theories are generally held: (1) taxation should be proportionate to the benefits received by the person or property taxed; and (2) taxation should be based on ability to pay. But who is to judge these benefits, and pronounce upon ability to pay? A third theory of taxation is to levy in proportion to the value and extent of the natural resources owned or controlled; in other words, to tax profits or net earnings. The net profits of a business are a simple measure of ability to pay, and also give some indication of the benefits received from enjoying the possession of the property. It may be said that, in principle, the taxing of net earnings is the theory on which the federal income tax is based, and it presumably bears heaviest on those that can best afford to pay. But taxation can be used—and has been used—to attain social and economic ends rather than merely to

gain revenue. It may be imposed to express social approval or disapproval. Heavy taxes may be used for conservational purposes, for example; while, on the other hand, in order to encourage certain industries, tax exemptions, protective tariffs, and bonuses on the production of certain commodities have frequently been legislated. Taxation must not be considered, then, as a straightforward payment for benefits received, but rather the best tax is that which is easiest to assess and collect and is, in the words of J. R. McCulloch, "at the same time more conducive to the public interests."

One thing is certain; the best tax should not violate the fundamental principle laid down by Adam Smith in 1776:

> The tax which the individual is bound to pay ought to be certain, and not arbitrary. The time of payment, the manner of payment, the quantity to be paid, ought all to be clear and plain to the contributor, and to every other person. Where it is otherwise, every person subject to the tax is put more or less in the power of the tax gatherer, who can either aggravate the tax upon any obnoxious contributor, or extort, by the terror of such aggravation, some present or perquisite to himself.[9]

The history of the federal income tax shows a slow groping toward a recognition of the fundamental peculiarity that mining property is a wasting asset and that the output of a mine is in part a return of capital. A form of income tax was imposed, repealed, and re-enacted during the Civil War, and was abolished in 1870. Another, passed in 1894, was held unconstitutional by the Supreme Court. In 1909 a corporation excise tax was passed which was really an income tax in disguise. It was so defective in its application to mining corporations that it did not even recognize that mineral deposits are depleted in value every day they are worked, although it did allow a deduction from income for depreciation of property. It soon became apparent that the taxation of incomes by the federal government could not be made legal without an amendment of the Constitution, and in 1913 the Sixteenth Amendment was passed, giving Congress "power to lay and collect taxes on incomes, from whatever sources derived, without apportionment among the several states, and without regard to any census or enumeration." The law of 1913 recognized, for the first time, that not only should mining companies be allowed a reasonable deduction for depreciation but should also be granted an allowance to provide for depletion of deposit. Although the law contained provisions that discriminated against a number of mining companies, the Internal

[9] Smith, Adam, *The Wealth of Nations*, Book V, chap. 2.

Revenue office, faced as it was with the almost hopeless task of valuing mining properties and attempting to reach an exact tax figure, tried to make an equitable interpretation of the laws, and the attitude of the revenue experts has almost invariably been open-minded and helpful in dealing with the tax-paying companies. A number of the greatest abuses have been adjusted in this spirit, the most recent of which centers about the provisions for depletion allowance.

Depletion, in the sense used by taxing officials, is compensation for loss or reduction in value as a result of the production and sale of minerals and mineral products. In the Federal Revenue Act of 1928, Section 114 (*b*) (2), the basis for depletion of mines discovered after February 28, 1913, was given as "the fair market value of the property at the date of discovery or within thirty days thereafter." It was objected, by sundry representatives of the mining industry at hearings[10] before a joint Congressional committee on internal revenue taxation in December 1930, that this requirement imposed upon the Treasury Department the necessity for doing something that could not be done. These mining men further pointed out that all mineral, known and unknown, in the property of an owner is *capital* and is consumed in the process of making profits; while the revenue law fallaciously assumed that only the amount of ore known to be present at an arbitrary date is capital, and all ore later discovered is *income* and taxable as such. These men, in an effort to rule out the necessity for the Treasury Department to attempt to place capital valuations on all mines, proposed that the requirement be replaced by a depletion allowance equal to 33⅓ per cent of the taxpayer's net income. They argued that the percentage allowance method, which had been proved successful in Canada, would substitute a single and accurate yardstick for the valuation of mineral properties and would give the following advantages over the existing method: simplicity, accurate and easily determined basis, economy of administration, prompt settlement, and equality to all taxpayers. As a result of the hearing, a change was made in the Revenue Act of 1932 to give an allowance for depletion, in the case of metal mines, of 15 per cent of the gross income from the property during the taxable year, excluding from such gross income an amount equal to any rents or royalties paid or incurred by the taxpayer in respect of the property. Such allowance shall not exceed

[10] *Depletion of Mines: Hearings before the Joint Committee on Internal Revenue Taxation, Dec. 9–12, 1930.*

50 per cent of the net income of the taxpayer. The taxpayer making return for the taxable year 1933 is given the option of electing whether the depletion allowance for his property for succeeding years is to be computed with or without reference to percentage depletion. Although the percentage allowance adopted is less than half the figure suggested at the hearings, and no distinction is made between iron mines and non-ferrous metal mines, the change in the statute gives the taxpayer the option of using the stated percentage allowance. It is not yet possible to determine how this change in the revenue act will be looked upon by the taxpayers on metal mines.

THE EXPERT WITNESS

Mr. Max W. Ball, in the *American Bar Association Journal,* has given an analysis of the expert witness that ranks as a classic in the literature of mining economy.

> Speaking solely for myself (and I have no brief to speak for anyone else), I find the giving of expert testimony one of the most challenging and stimulating of professional experiences. The reason is simple: A man's work either stands up or is shown up on the spot. If the cross-examination is informed and skillful—and heaven help the witness who expects anything less—he will know when he steps down from the stand whether he has done a good job or bungled. The sharp and searching test of his knowledge and presentation, and the immediacy with which he can taste pride of accomplishment or shame for failure—these make the expert's day in court exciting and on occasion satisfying. They also make it advisable for him to consider seriously what qualities he requires to pass the test and to taste pride more often than shame at the end of it.[11]

He then proceeds to discuss in detail six requirements that condition success in this field of law:

> These, then, it seems to me, are the things that a man should require of himself if he goes on the stand as an expert: (1) honesty so sincere it will permit no evasion, (2) wholehearted partisanship in his client's cause, (3) interest in every aspect of the case in which he is qualified to be helpful, (4) readiness to abide by the decisions of counsel, (5) such thoroughness of preparation and such ability to put himself in the position of judge or juror or commissioner that he can make his evidence clear to them, and (6) such freedom from condescension or arrogance that he creates friendliness rather than hostility toward his client's case.
>
> These requirements do not seem impossible or immoderate; they should be within the capacity of every professional man of reasonable ability and experience.

[11] *American Bar Association Journal,* Vol. 29 (December 1943), pp. 695–97.

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Part Three

MINE MANAGEMENT

Chapter 20

Organization of Mine Staff

Management is the executive function in industry. Its aim is to carry out, in the most efficient and economical manner, the administrative policies of the business. In a report approved by the Committee on Management of the American Society of Mechanical Engineers management is defined as "the art and science of preparing, organizing, and directing human effort applied to control the forces and utilize the materials of nature for the benefit of man." Briefly, the elements with which management has to deal are men, money, methods, machinery, materials, and markets; and the management will be directly responsible for any waste in the utilization of these elements.

THEORY OF MANAGEMENT

The relation of management to administration and organization has been set forth by Oliver Sheldon:

> Organization is the formation of an effective machine; management, of an effective executive; administration, of an effective direction. Administration determines the organization; management uses it. Administration defines the goal; management strives towards it. Organization is the machine of management in its achievement of the ends determined by administration.[1]

The application of the engineering method to the problems of management has led to the present development of the technique that is variously termed "scientific management," "industrial engineering," "production engineering," "efficiency engineering," "industrial planning," and "rationalization" in the sense used by such British writers as L. J. Barley, who defines this concept as "the scientific reorganization of industry with the object of obtaining the maximum profitable production of goods and a higher standard of living for the community without unfair exploitation of any one class."[2]

[1] Sheldon, Oliver, *The Philosophy of Management*, p. 31.

[2] Barley, L. J., *The Riddle of Rationalization*, p. 33.

This definition of "management" is strongly reminiscent of the definition of "civilization" already given above (p. 2). The growth of the scientific management movement and its principles will form the subject of chapter 22.

Our civilization requires a tremendous supply of minerals to sustain its existence. The administrative ideal that management in the mining industry seeks to attain is the satisfaction of this demand in the most economical manner. The test of management is therefore the amount of *profit* that is won in the enterprise. It should be understood that profit is here used in the sense of accumulated benefit or value. It is conventional to express this profit or gain in monetary terms, but profit should be considered as something more than merely interest or dividends on capital. Profit may accrue in the form of an increase in goods, a wider variety of services, a saving in expenditure, a lightening of the burden of human toil, an accession of greater welfare and happiness to a greater number of beings. These imponderables are often translated into monetary terms for the purpose of estimating the economic value of a project (such as expenditure for public works like bridges or highways, which are paid for by taxes and should return a profit through saving or increased usefulness to the population as a whole); but the dollar is merely a convenient, if imperfect, measure of profit in this broader sense. Even the most rabid communist does not wish to abolish profit as such; he may hope for a different distribution of profit than that prevailing under our capitalistic system, but if money were abolished overnight some other single measure of profit would inevitably be needed to fill its place.

The efficiency of management, then, is measured by the ratio of profit obtained to the sum total of potential power placed under its control. The difference between these two factors constitutes economic loss or waste. This waste in industry is in great measure directly attributable to inefficiency in management; a committee of the Federated American Engineering Societies estimated that inefficient management was responsible for from 50 to 80 per cent of the waste in all industries, and in view of the hazardous nature of the mining industry it is probable that the estimate for mining would be considerably greater than this figure.

Even as the attempt to increase the efficiency of machines is an engineering problem, so the attempt to eliminate waste and to heighten the productivity of any industry is primarily a challenge to the engineering type of mind. If the human element is added to the

other factors of the project, the engineering method of approach outlined in chapter 1 is the best technique for the integration of the problem of efficiency in management.

The steps in the satisfaction of a human need through the medium of an engineering project were listed in the introductory chapter of this book. It was also stated that management is a separate function that is called for all along the line, one which is necessary for the co-ordination, control, and direction of all these activities. The schematic analysis of an engineering project will bear repetition here, as it shows clearly the functional relation of management to the other functions of a mining business. Thus:

1. Research and invention 2. Valuation and finance 3. Organization and promotion 4. Design and construction 5. Operation and production 6. Maintenance and safety 7. Testing and inspection 8. Sales and distribution	Management

The management function is exercised, with more or less success, at every point where any responsibility is assumed or any work is to be accomplished. Even the most individualistic artisan or research worker must organize his materials, apportion his time, arrange his working-habits, and adjust his relations with others if anything of value is to be produced.

As the individual develops his innate talents and increases his skill in planning and executing the tasks for which he is responsible he becomes more fitted to assume greater responsibility and to direct the activities of larger and larger groups. The executive who is placed in control of the immense industrial enterprises of the modern world, although his duties and powers are greater in degree than those of the foreman who immediately directs the performance of labor, has merely attained a special skill in applying those principles of efficient application of effort that govern all workers. These principles apply likewise to the production of profit in all industries, although, of course, the technical details vary greatly from one industry to another. In other words, the manager of a mine, in his capacity as manager rather than as technician, exercises the same skill as does the manager of any other business enterprise.

Nevertheless, the executive will be seriously hampered if he does not have a good understanding of the particular difficulties that are

to be encountered in a given task, and therefore the men in control of mineral production should be fully aware of all the factors in the mining business that may lead to waste and inefficiency. The need for efficient management may be said to be greater in the mining industry than in almost any other, for in addition to all the hazards of manufacturing industries the mining business is beset with a number of special risks that may cause a great waste of time, money, resources, and power, both human and mechanical.

The risks in mining have been itemized in chapters 2 and 17, as well as in other parts of this book. They consist of the difficulty of discovering the mineral deposits distributed in an erratic manner through the earth's crust, the hazards that menace the safe and economical extraction and treatment of the metal, fluctuations in costs and prices of products, and the need for undertaking extensive development work and installing large plants and power units some time before any money can be realized by sale of product. These risks which are assumed by necessity have led to tremendous financial inefficiency caused by the failure of a large proportion of mining enterprises, terrific overhead charges for many companies, speculation, overcapitalization, undercapitalization, unplanned production, and a waste of wealth in the promotion of parasitic, worthless, or fraudulent schemes. Moreover, the general principles of industrial engineering must be modified to take into account the special technical difficulties involved in wresting useful minerals from the depths of the earth. Metal ore must be worked wherever it can be found. Mass production such as that carried on in the assembling industries cannot very often or completely be applied to mining. The job cannot be brought to the worker; he and his tools must be transported underground to the stope where he labors, and much time and power is consumed merely in making it possible for the work to proceed with fair speed and safety. The surface plant cannot be located for convenience, as can a factory site; the mill must follow the mine, and must be built to fit the mine, regardless of difficulties of topography and distance. Almost all mines are in out-of-the-way districts that lack most of the facilities of civilization, and hence the mine executives are often responsible for the growth of the entire community—roads, railways, housing, and stores—and for the provision and regulation of police and fire protection, and of health, welfare, and other services performed by civil officers in ordinary communities. Moreover, the average mine laborer is likely to be a man of little education and sometimes of a violent nature, and grave

disciplinary questions are sure to arise sooner or later in the course of the work.

These are but a few of the problems that the mine manager must face in his efforts to establish an efficient organization. It is not to be expected that he will attain complete efficiency, but as he increases in his understanding of the principles of leadership and scientific management he will be enabled to cut down many of the tremendous wastes that have crippled the mining industry in the past.

Part Three of this book is devoted to some of the chief problems of mine management: staff organization and duties; the manager; efficiency methods; wages and labor problems; discipline; research, analysis, and planning; training of personnel; and safety, health, and welfare. The concluding chapter will present a view of the opportunities and responsibilities of the profession of mining engineering.

MINE-STAFF ORGANIZATION

The structure of modern mining companies has been described in chapter 13, in which place it was pointed out that authority is delegated by the shareholders to the board of directors and other administrative officers, who in turn pass on authority and responsibility to the manager in charge of the production force. The manager is thus the king-pin in any co-operative organization, for it devolves upon him to carry the administrative policies to success.

It is obvious that no one man can undertake to perform all the managerial functions of a mine of any size. He must delegate parts of his work to suitable subordinates under his direction, allotting to them enough authority to insure the performance of the functions for which they are held responsible. Some of these subordinates may act only in an advisory capacity or may also be charged with the leadership and control of lesser subordinates, technicians, and laborers. The personnel under the manager may be bound together into an efficient human machine to apply economically the power placed in its hands, or it may become a disorderly, disconnected, sprawling monster the parts of which are not in harmony and which can lead only to friction, waste, and ultimate failure. It is the task of the manager to organize and direct an efficient personnel to carry out the particular production needs of the company that he represents.

Types of personnel organization.—Several types of organization have evolved during the growth of industry. The first of these to develop was the *departmental* plan, by which the production force

was divided into separate units according to the various technical processes to be performed. As this was equivalent to setting up an individual organization for each department it easily led to lack of coherence and co-operation among the different departments, to duplication of efforts and functions, and to corresponding high costs, conflicting policies, and general inefficiency. In industries where specialization of processes extends down to every act of the individual workman, however, this straight-line plan may be very effective, especially in those assembling industries where a departmental scheme may be adapted to performance of work on a continuous-process program.

Again, an industrial organization may be divided on the basis of *function;* that is, many of the same functions appear in all the various departments of the process, and these functions—such as purchasing, transportation, maintenance, inspection, research, and the like—may be controlled by executive specialists whose spheres of action are not limited by department lines. In this way, the heads of departments are able to concentrate upon the supervision of direct production, leaving the auxiliary services in charge of the specialists in each field. The dangers of this type of organization, however, are apparent: weakening of line authority, dual control and possible lack of co-operation, and consequent confusion.

A third type of organization has resulted from a combination of the two mentioned. This *line and staff* plan, as it is called, allots to the line or departmental organization the routine duties of production and further provides a staff of advisory specialists charged with the duty of studying methods, making analyses, co-ordinating processes, doing research on new problems, planning the future course of procedure, and otherwise showing the way to increased efficiency. The staff executives, although they may have assistants under them to help in the performance of their duties, do not ordinarily exert authority over the line organization directly, but only through the manager acting upon their recommendation. The line-and-staff form of organization is best fitted to such an activity as the operation of a mine, where procedure is not capable of standardization throughout and new problems arise frequently. The mine-organization chart shown in Figure 10 is of the line-and-staff type: of the executives under the general manager only the mining engineer and the metallurgical engineer are line officers in charge of direct *production;* all the others supervise the performance of *functions* that are not limited by departmental boundaries.

A fourth plan of organization, the *committee plan,* has often been proposed as a form of management. No business can be efficiently controlled by committee action, because this form inevitably leads to delay and indecision. However, advisory, executive, educational, and inter-departmental committees may serve useful purposes as an auxiliary to the executive. The board of directors is itself a committee of stockholders.

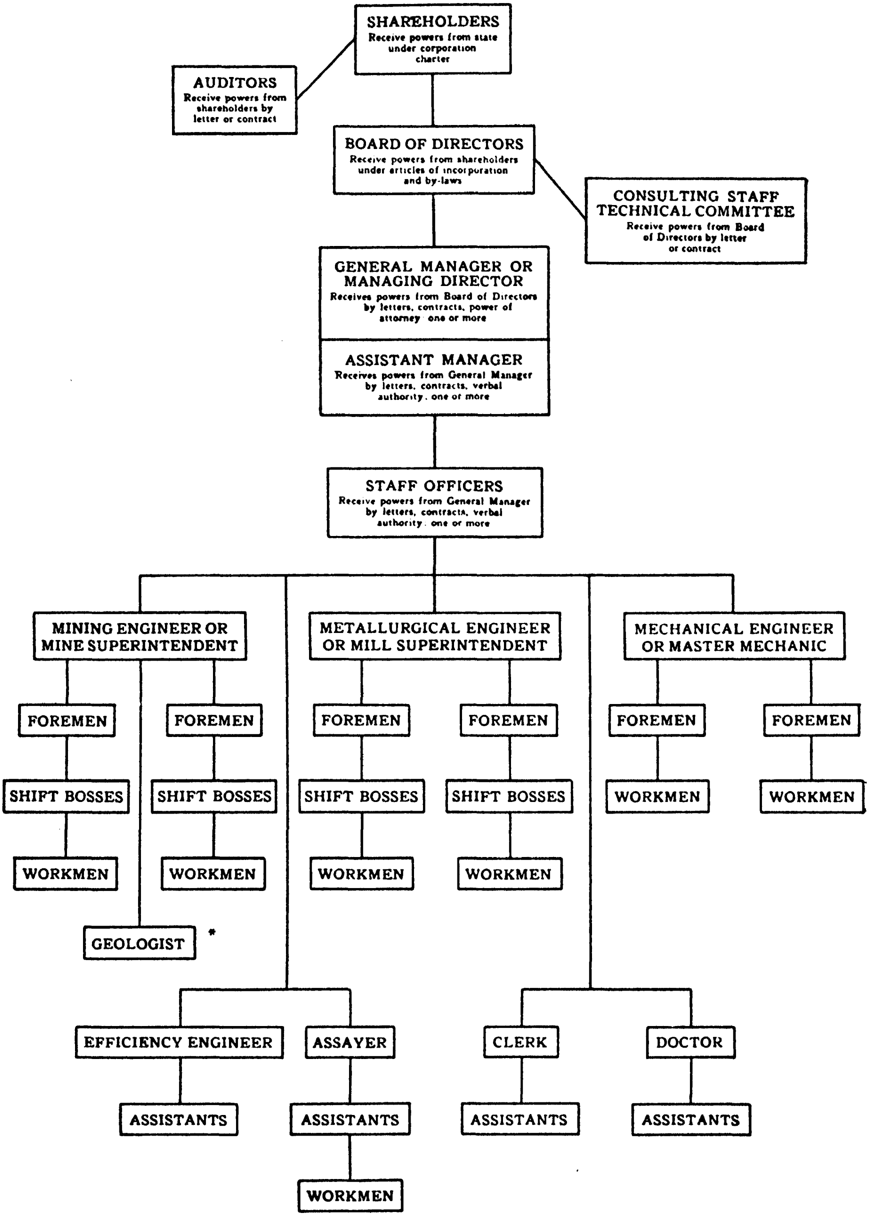
Organization chart of a mining company.—The line of subdivision of authority and responsibility in a mining company of medium or large size is shown in Figure 10. There are, of course, many other possible combinations of the human units of authority, but this skeleton plan will serve to show the flow of authority from the ultimate source (the stockholders) through its elected administrative representatives (the board of directors) to the general manager and his various advisers and assistants who guide the efforts of the rank and file of personnel. The interrelations of the various officers who serve on the manager's staff, and their relations to the manager, are shown in chapter 21, Figure 11 (p. 408).

Only mines of the largest size would have all the officers shown in Figure 10 (p. 390). Mines of medium size would reduce the units by combining the duties or two or more below the rank of manager; and it is conceivable that at a very small mine the manager would carry on the functions of almost all the staff positions.

DUTIES AND QUALIFICATIONS OF MINE STAFF

Conforming to the plan shown in Figure 10, the duties and qualifications of the various co-operative groups and administrative and executive heads in a mining organization may be briefly described.

Shareholders.—The shareholders are the owners of the property and the ultimate employers of all the personnel. They delegate most of their authority to an administrative board of directors elected by them, and once the articles of incorporation and by-laws of the company have been approved the shareholders can exercise administrative functions only indirectly, by means of electing new directors to replace those unfavorable to their intentions. The shareholders also retain for themselves the right to appoint auditors to check the annual financial reports, and to vote on certain routine matters at the general meetings.



* In many important mines the geologist is not subordinate to the mining engineer but is of equal rank and has complete charge of initiating all development work.

FIG. 10.—Organization Chart Showing Flow of Authority in a Mining Company

Board of directors.—The board of directors meets at stated intervals and acts as an administrative body, outlining the policies of the company and approving or disapproving the acts of the mine management. Board officers, such as president, secretary, and treasurer, are elected to perform various duties that will assist the board as a whole to act as business men in charge of the company's activities. The qualities that make a good director are noted in chapter 15, pp. 292–93.

Consulting staff: technical committee.—The board of directors will often desire expert legal or technical advice, and may sometimes maintain a consulting engineer or technical committee. Rarely is there any delegation of authority from the board to such a consulting engineer or committee, and this office is seldom more than that of a confidential advisory service.

The position of consulting engineer is sometimes one of great influence in the affairs of a company, however, because he sits close to the directors and can therefore readily discuss with them any plans affecting the future of the property. Frequently he is required to read and analyze all of the reports and data coming from the staff of the mine and to explain their meaning to the board. He serves as a check upon the technological actions of the mine manager, and may be asked to visit the mine and report upon the current situation. The position of consulting engineer is sometimes conferred upon a manager as a promotion; and there have been cases where a manager whom the directors were afraid to discharge has been "kicked upstairs" and given a high salary and little to do. Consultants may serve more than one company, if the various interests do not conflict.

The technical committee is a recent development in mine management. It is made up of engineers each of whom has some special qualification that enables him to advise the board on certain phases of its business. It is, in effect, a committee of consulting engineers. Only the very largest of mines could afford or justify such an aid in good management. There is undoubtedly wisdom in council, and when a mining company has a technical committee composed of specialists in geology, smelting, concentrating, and mining it should have few errors in engineering. The technical committee should read and analyze all the data coming from the mine and should meet at least weekly to discuss matters. This committee, like the consulting engineer, will probably have no power of discipline or appointment except that which comes from intimate advice and counsel with the board.

General manager, superintendent, or managing director.—The general manager or superintendent is the executive field officer of the mining company. He is directly responsible to the board of directors for all activities at the mine, and all subordinate officers—since he is responsible for their acts and must co-operate with them—should be appointed with his approval. His authority should be unchallengeable by any official below the board of directors.

Some boards of directors appoint one of their number as managing director, or give the mine manager a seat on the board. It is an excellent plan to admit the manager to membership in the body whose actions will have a profound effect upon his activities. However, the mine manager should always reside at the mine site most of the time (he may, of course, manage a group of small mines and in that case will travel from one to another as conditions require). A mining property is far from being so free from hazards and emergencies that it can be run by a man sitting in an upholstered office chair two thousand miles away.

The qualities that make a good mine manager and the ideals of leadership that should be personified in him are of such great importance that chapter 21 has been devoted to a discussion of them.

Full charge of all activities at the mine, including complete executive control of the resident personnel, is given to the manager by virtue of authority bestowed by the board of directors in the form of a contract, written instructions, power of attorney, or all three. The number of immediate members of his staff who are to supervise the work of the various departments or perform certain advisory functions will vary according to the size of the enterprise. In general, the various divisions of work will be divided into mining engineering, metallurgical engineering, mechanical engineering, assaying, efficiency engineering, clerical work, and medical care. Two or more of these functions may be performed by the same individual on a small mine staff, while, on the other hand, at a large mine the functions may be further divided into a number of subdivisions each headed by a responsible staff executive. This classification, however, will be found useful in describing the duties of the officers who serve as the general staff of the mine manager.

Assistant manager.—Mining companies frequently find that they can afford to maintain an assistant manager who is trained to take the manager's place temporarily and who is in line for promotion if the manager vacates his position. It will usually be much more economical to replace a manager by a trained assistant familiar with

the company's policies and operations than to import, from elsewhere, a new manager, who must learn these things at a great waste of time and money and whose unfamiliarity with conditions may easily lead to failure.

All of the qualities of a good manager are requisite in an assistant manager. If a man on trial does not reveal these qualities he should be dispensed with and his place given to another candidate. He should in no event be reduced in rank and retained at the mine. This rule holds good for all members of the personnel: no man who has been demoted in rank should continue on the staff. If he has been reduced through no fault of his own it is even worse to retain him, for his grievance is even more acute; removal may work a personal hardship, but a man whose authority has been curtailed is a disciplinary danger-spot in any organization.

It is customary in many places to give the duties and title of assistant manager to one of the staff officers who has had technical training and has displayed qualities of leadership. Thus, the mine superintendent, mill superintendent, assayer, geologist, efficiency engineer, or master mechanic may also serve as assistant to the manager and receive some training in supervising all operations. Each of these men, provided he has the requisite executive ability, is in line for promotion to managership.

Mining engineer or mine superintendent.—Although other staff officers may have been trained as mining engineers, the man in charge of development and extraction of ore—usually called the mine superintendent—will be the most important member of the manager's staff, for upon him depends the production of the raw materials without which the services of all the other departments would be useless. The mine superintendent may have reached his position by passing through any one of the four subordinate mine ranks: foreman, geologist, sampler, or surveyor. (At a small mine all of these offices may be combined in one man.) The ideal mine superintendent should be a trained mining engineer with special knowledge of economic geology, ore formations, and mineralogy. He may be, in fact, the geologist of the staff, although at some large mines there may be an officer who devotes all his attention to this subject. The mine superintendent's education, combined with his practical experience, should have given him facility in handling rock and timber, in the use of drills, compressors, blasting, hoists, engines, and light railways, in designing and constructing timber framing, and in ventilating the mine and controlling flood waters by

pumps. Above all, he should have acquired the essentials of leadership and a comprehension of workman psychology.

His immediate assistants are the geologist, the surveyor, the sampler, the foremen, and the shift bosses. The force under him may consist of workers designated by such terms as miners, shaftmen, muckers, trammers, chutemen, trackmen, pipemen, timbermen, powdermen, station-tenders, ore pickers, etc.

The duties of the geologist and mine surveyor have been outlined at the beginning of chapter 5. The sampler's work is given detailed mention in chapters 3 and 4.

Metallurgical engineer or mill superintendent.—The metallurgical engineer is in direct control of all ore-treatment operations, and he is responsible for the processes used to recover the maximum quantity of valuable mineral products and for the proper use of machinery and supplies provided for the purpose. He may have passed through all the grades of promotion in the treatment plant or smelter, from sweeper to foreman. His knowledge of chemistry and metallurgy should be thorough and grounded on experience as well as education, and he should also have a good understanding of mechanical engineering to enable him to get the best service from the equipment employed in ore-dressing and transportation. He will be assisted by foremen in the concentrator, cyanide plant, smelter, or the like.

Mechanical engineer or master mechanic.—The mechanical engineer is in charge of the construction and maintenance of the mechanical and electrical plant at the mine and the treatment plant. He should conduct regular and complete inspections to see that the efficiency of the various machines remains high and to repair or replace equipment before danger limits are reached. The average college graduate in mechanical engineering is not sufficiently well equipped in mining and metallurgy to make an ideal candidate for this position; but a mining engineer who has specialized in mechanical engineering, or a mechanical and electrical engineer who has specialized in geology, metallurgy, and chemistry, would be excellently fitted for the post of either mine superintendent or mechanical engineer, and his technical training would further fit him for promotion to the managership. He should, in the course of his experience, attain a facility in the design, erection, and operation of nearly all the machinery and electrical equipment used in the mine, mill, smelter, power, and railway plants, and should also be able to direct

the men under him efficiently. His chief assistants may be the head draftsman, the millwright, the machine-shop foreman, the railway foreman, the power-plant foreman, the road boss, the head carpenter, the blacksmith, and so on, in charge of laborers in the various trades.

Assayer.—The assayer or chemist is given the duty of performing and reporting all analytic work on samples from mine or treatment plant. He should have the same general training as the metallurgist, and at many mines is in line for promotion to the position of metallurgical engineer. The instinct for scientific research is an admirable trait in the assayer, provided he has a sense of proportion that will cause him to limit his experiments so that they may lead to practicable processes. By the time a man works through the lower grades in the assay office of a large company and becomes chief of the assay staff he should have acquired a voluminous knowledge of the chemistry and metallurgy of the ore mined and should thus be able to speak more authoritatively on these subjects than any other member of the organization. His assistants may be few in number and he may therefore have less opportunity to display qualities of leadership, but if he nevertheless is able to demonstrate skill in handling men he will be in line for promotion to a higher executive position.

Efficiency engineer.—The duties pertaining to the position of efficiency engineer have not crystallized during the few years since the need for such a post was fully perceived by able mine managers, but there is no doubt that in the proper organization of large mining companies the efficiency engineer, or his functional entity, is an essential. Primarily, his duty is to observe, study, and make recommendations upon any parts of the company's operations which might be performed more effectively in accordance with administrative policies—both in use of equipment and in the better functioning of human units. The efficiency engineer is often given supervision of a number of assorted activities such as "safety-first" training, education, company library, welfare work, and collection of statistics. He is sometimes called upon to represent the company in its relations with labor, and may be given charge of the company employment bureau (although this may be the duty of the head timekeeper or an employment manager under the chief clerk). The position of efficiency engineer might well be attractive to a young man trained in engineering and specializing in economics and scientific management, which subject is discussed in chapter 22.

The efficiency engineer will not ordinarily have many assistants,

but he will be given frequent opportunities to demonstrate the tact in dealing with men that should form his chief characteristic.

Chief clerk.—The chief clerk is charged with keeping all the records and accounts of the company up to date and managing the general office of the mine. He may be merely a good bookkeeper who has won promotion; some of the best clerks, however, are mining and metallurgical engineers who have had adequate training in accounting, economics, and business methods. Such an engineer-clerk would not be barred from promotion to managership via this route. The clerk is usually assisted by, or performs the duties of, the accountant, who supervises the payroll and checks bills and invoices; the timekeeper, who reports the number of men at work and their hours; and the purchasing agent, storekeeper, or supply clerk, who purchases and delivers supplies on requisition, keeps accounts, and makes periodic inventories.

Doctor.—The company may retain a local physician to provide medical care for employees, or a medical man may be a part of the regular staff, in charge of the company hospital and dispensary. He should also be given power to recommend health precautions and to supervise the sanitary arrangements of the mine district and company buildings, such as change houses, boarding-houses, or dormitories. The doctor is almost never considered a candidate for mine managership; his future lies in his own profession. His function is an important one in most mines, because of the accident risks in mining, the dangerous health conditions prevailing in many mining countries, and the fact that many mining camps lack the medical facilities to be found in more settled communities.

Foremen.—The foremen on the mining-company staff are the noncommissioned officers, whose duty it is to direct and assist the rank and file of laborers to perform their tasks properly. Most of these men have at best a high-school education and by virtue of superior natural talent and perseverance have worked up from the bottom. There is an advantage in having foremen of this type, for they are generally content to remain in their positions and act as wheelhorses for the organization, helping to maintain a continuous tradition on the job; whereas the exclusive employment of college men who would probably desire rapid advancement would considerably disturb routine performance and cause a possible slackness of organization. A middle course is advisable, keeping the "non-com" type of foreman in most positions and making special cases of a few

foreman positions for the purpose of training candidates for higher executive posts. It is desirable that most foreman jobs be kept open for the advancement of non-university men of superior intelligence and ambition.

The mine foremen, and the subordinate shift bosses chosen by them, are on the firing-line underground. It is their duty to build up an efficient crew of miners and helpers, to inspect their work at least once every shift, and to report all new ore developments to the mine superintendent and the manager. In lesser degree, all the executive qualities needed in higher positions should be displayed by the good foreman. The mine foreman is the lineal descendant of the old Cornish mining "captain," except that all his geologic and mineralogic functions have been taken over by the geological staff. No one is more prone to theorize on mineral formations than the practical hard-rock man, although his chronic optimism makes him a poor person to intrust with routine sampling—if his practiced eye lights on a piece of "specimen" ore he cannot ordinarily resist the temptation of putting it into the sample bag. The better type of old-fashioned mine foreman had a keen eye for ore, and some of his geological deductions are wonderful examples of arriving at correct conclusions by faulty methods of reasoning corrected by intuition.

Surface workmen, shop crews, and special gangs of workers performing auxiliary and maintenance functions throughout the plant are supervised by foremen or shift bosses selected from the ranks, who receive higher pay for their work. On the other hand, certain posts such as that of power-plant foreman or railway head, charged with the supervision of highly technical work, will nearly always be filled by university-trained engineers, who may in some cases even occupy a rank equal to that of other staff officers.

Staff supernumeraries.—There are certain members of the mining community who may not appear on the company payroll but who nevertheless exert a tremendous influence on the proper functioning of the manager's staff and may therefore receive brief mention.

Women are an indispensable adjunct to a mining community, and any mine manager who thinks he can run a mine without securing the co-operation of the women associated with the community—not only those serving as stenographers, clerks, and other aids among the personnel, but chiefly those related to staff members—is likely to be speedily disillusioned. General Gorgas is reported to have said that the difficulties created by women relatives of the builders of

the Panama Canal were greater than those arising from the actual work of constructing the Canal. When a company hires a mining engineer it is, in reality, employing his wife as well. More than one engineer, capable of filling the most important positions in his profession, has had to sacrifice his managership because his wife continually fomented trouble in the mining community, disrupting the staff by resignations and impaired efficiency. It is, of course, not always the wife of the manager who creates ill feeling; trouble may arise in the household of some subordinate staff member, and usually culminates in the necessity for the unfortunate husband to seek employment elsewhere. The main causes of trouble of this nature are jealousy regarding preference or advancement, inequality of housing of the staff, gossip, and quarrels about children.

The mine staff must necessarily have many contacts with civil officers and prominent citizens of the community. Efforts on the part of the staff members may make these men a valuable supernumerary group, willing to co-operate with the company in many ways, or by thoughtless antagonism they may become alienated and lend their influence to obstructing the smooth operation of the company's administration. The hostility of elected county or state officials may be a decided hindrance to successful operations, but such a condition does not often occur if the manager and staff are the normal type of engineers and technologists.

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Chapter 21

The Mine Manager

The idea that a good mine manager must be a superman or a demigod will not bear scrutiny. Men do not vary greatly in their abilities; but slight variations in skill and training may make all the difference between success and failure. An inefficient manager may run a rich mine without loss for a time, but when the winds of adversity blow his weakness will be revealed. Although it has been said that "no complete manual will ever be published upon 'How to Become a Good Mine Manager,'"[1] experience has shown that certain general rules of procedure in the execution of mining enterprises may be depended upon to bring the best results, and that many of the qualities revealed by good mine managers may be consciously developed by training and practice.

QUALITIES OF A SUCCESSFUL MINE MANAGER

What are the personal qualities that make a good mine manager? They may be summarized as follows:

Organizing ability.—The ideal manager should have the organizing habit of mind. He should be able to plan a task, to envisage all the factors that must be dealt with in order to accomplish his purpose, and through the process of integration to arrive at a solution. The organization of men and materials to perform a given job is a function that engineers must continually perform. The efficient handling of materials results from the engineer's technical training and experience; the methods used to promote the co-operation and effort of human units may also be derived from experience and from deliberate attempts to apply the axioms of practical psychology.

Some mine managers who are weak in organizing ability try to do too much of the executive work of the mine; they show a lack of confidence in themselves by being fearful of delegating power to subordinates. Worse, they sometimes, after charging a subordinate

[1] Hoover, H. C., *Principles of Mining*, p. 161.

with the performance of a duty, interfere with his actions, countermand his orders, and otherwise impair his efficiency by appearing to distrust his judgment and by failing to back up his decisions.

Understanding of human nature.—A practical understanding of the workings of the human mind under various situations will enable the manager to select the most efficient personnel and to deal with the disciplinary problems that will inevitably arise in any organization.

The selection of men to perform the various functions of the work, and the supervision and encouragement of their efforts, will consume a large part of the manager's energies. The perversity of human nature will never cease to be a wondrous perplexity to the executive; but the chief moral difficulty he will have to face involves the infraction of rules of common, ordinary honesty—not so much honesty as regards stealing or fraud but that more dangerous slackness in thinking and acting in accordance with common concepts of intelligent behavior; in a word, mental dishonesty.

Careful observation of a number of men on the staff of a mine will reveal that, from this point of view, they will fall into three main groups. First, there is the all too small group whose minds are systematically and constitutionally honest. They run true not because they consciously intend to uphold a high moral code but rather because they are born engineers who apply the method of rational integration from instinct; they habitually reject any line of action based on error as they see it, and, like a skilful driver, they do this with ease. The second class may be equally ambitious, intelligent, and informed, but its members tend unconsciously to follow the line of least resistance. This habit may lead them into situations that could have been avoided had they taken the time and effort to weigh all pertinent factors and act boldly upon their decision. Having slipped, perhaps inadvertently, into a false position by thus taking the easiest way, such men may set about an elaborate justification which involves piling false upon false. The facts may be craftily hidden for a time, but the chance of ultimate revelation of the falsehood is proverbial. Minds of this type are a menace to the establishment of an efficient staff, and every manager intrusted with the administration of large affairs should weed out such men without compunction; the risks of failure in a mining business are too great for a manager to take on the additional burden of attempting to reform the warped mental habits of human beings with whom he has by chance been thrown into association. The third group consists of the petty grafter and slacker—the man who runs when the whistle blows and

whose perpetual delight it is to "put one over on the old man." Such perverted wasters and professional liars should be eliminated from the personnel by the quickest means at hand.

Business instinct.—A mine under the old cost-book system in England was usually managed by one of the adventurers, who served as the business head of the company, leaving the details of actual exploitation to a mining captain, who was no more than a skilled miner. This system was based on the fallacy that the technologist could not be a good business man. On the contrary, although a mine manager needs a sound knowledge of technical methods, he serves primarily as a business executive, and should have a highly developed commercial instinct.

Education.—The best background for a mining engineer is the six-year course given in some American universities. Most of our American mining engineers are, however, the product of the four-year course; their shining records attest its value. University training for mining and metallurgical engineers should aim to give a broad cultural basis, scientific habits of mind, and a mental elasticity through class discussion and laboratory practice. A few months of contact with his profession in the field will give the engineer all the "practical" drill needed, for if his training has properly developed his outlook he can readily absorb the details of processes and the expedient methods of procedure. It is needless to say that the education of the mining and metallurgical engineer never ends as long as he is dealing with men and materials.

The old idea that there are two sorts of manager—the "expert" and the "practical man"—is absurd; there is no successful mine manager anywhere who is not both practical and well informed, even though he may have lacked opportunities for formal education. Those eminently successful engineers who lacked educational opportunities are the last to claim that this was an advantage to them and the first to admit that this lack was a handicap to rapid advancement in their profession. The chief disadvantage under which the self-educated man labors is a feeling of inferiority in comparison with his more fortunate associate; this may lead to hesitancy for fear that he may be wrong, and thus cause a loss of confidence that is fatal to an executive.

It is not reasonable to expect any mine manager to command an expert knowledge of all the technical details of the various depart-

ments. The path to managership may lead through any one of a number of branches—mine, mill, smelter, assay office, geological staff, general office—or the manager may even conceivably come from a different industry altogether; and he therefore may be excused for a lack of skill in solving all problems of detail. But he should have acquired, in the course of his career, sufficient contact with all of the departments to give him a fairly broad conception of the activities and possibilities of each, so that he may choose a suitable personnel for these branches and may further be able to allot each department its proper place in the complex process of discovering and producing metals for the use of mankind.

Vision.—A measure of the efficiency of a manager, if it could be measured, would be some statement of the relative preoccupation of his mind with the past, present, and future of his project. The manager whose mental processes revolve mostly about what he has done might conceivably be able to recite from memory the whole history of his project. A manager preoccupied with the present would be oblivious of his past mistakes but could paint an accurate current picture of his project. The manager preoccupied with the future would not be able to say much about what he had done, would be oblivious of his past mistakes, and could not give a very lucid account of what was going on. What the world wants in a manager is a good memory of what has happened in the past, a great awareness of what is going on at present, and a face turned to the future with all the forces of his mind and character marshaled for action.

Comparing the manager's position with those of his seven principal officers, one might say that the manager's office is equipped with a telescope and his subordinates are equipped with microscopes. Very often some of these subordinates will show in their daily work that they are capable of using a telescope as well as a microscope; such men are in line for promotion to greater executive responsibility. The others may be excellent men in their positions but they have not the vision required for the performance of greater duties.

Ambition and energy.—A good mine manager should be ambitious to achieve repute in his profession by creating an efficient organization, and should possess the energy to accomplish this difficult task by hard work. The engineer is not intended for a life of ease, and a man cannot manage a mine with his feet on a desk. It is not the whole of mine management to call in the staff once a day

and issue orders; staff meetings are worthless if the manager has not been over the ground personally at frequent intervals. Some managers grow lazy after the initial period of staff organization and neglect the arduous but important work of underground inspection. A staff can be vitalized into energetic co-operation, not by shouting orders, but by setting up the example of an alert executive who is always at the critical spot at the critical moment.

Decision.—The efficient manager must possess a large fund of confidence in himself and his judgments, based on the knowledge that his decisions are logical and sound. These should not be "snap" judgments to be countermanded the next moment, but must rather be the products of a careful engineering analysis of each situation, through the application of the engineering method of approach that has formed, and will continue to form, the unifying idea running through this entire book. An experienced executive may take a bundle of data, glance through it, and almost immediately render a sound decision that could be reached by his junior assistant only after devious pondering, if at all. This is possible not only because the manager may possess certain facts which are for one reason or another withheld from his subordinate, but mainly because experience in solving executive problems has developed the faculty of speedily and accurately *weighting* the various factors and integrating them in proportions that will give the most balanced solution at the time.

One type of manager is so jealous of his subordinates that it is impossible for him to build an efficient staff; he is afraid that a man of exceptional ability will work him out of his job. Such a fear is based on a lack of self-confidence, and a man of this nature will never become a real leader. The more inspiring type of manager takes the point of view that he wants his staff to consist of the best assistants that can be procured. He welcomes competition; if a subordinate feels he can work himself into the manager's shoes, he is invited to do so, providing it can be done by sheer ability, without resorting to petty intrigue. Such a manager has little to fear, for the self-confidence he possesses will create a demand for his services wherever there is executive work to be done.

Honesty.—It must be apparent that a manager cannot demand from his personnel a degree of mental and moral honesty greater than that which he himself displays on all occasions. He must not only be capable; he must be worthy of confidence and must demand from

himself a rigid and unvarying integrity of thought that discards sloppy thinking, self-delusion, and hazy compromise. A shifty and deceitful man, whose word is not always better than his bond, will never be a great leader, no matter how clever his tricks or how smart his shifts.

Fairness.—The manager should never "play favorites." Every man in his organization should be able to feel that he could come to the manager and receive the same unbiased judgment or encouragement that would be given to any other member deserving consideration.

No man should be allowed to continue to feel that more is demanded of him than is returned to him in the form of rewards and recognition. Neither should he be allowed to harbor resentment because another member of the organization is holding down a sinecure.

> The burden of the administrative work should be equitably divided. Each man should have sufficient to fully occupy his time but should not be overloaded. Underloading is probably more objectionable than overloading and a manager must be closely in contact with his men in order to make any necessary adjustments in the division of the work.[2]

Any exceptional application to work, extra service, or valuable suggestions should be recognized by executive commendation if more substantial rewards are not possible. No manager can long retain loyalty if he continually takes credit for ideas or improvements initiated by his subordinates; while, on the other hand, an assistant who for extra service is "cited in orders" will glow with satisfaction at this public recognition of his worth and will be encouraged to keep up the good work.

Inspiring loyalty.—The ideal mine manager will inspire loyalty by setting up an example of leadership. The greatest asset that a mine can have is to be found in a high degree of loyal co-operation by the human units that make production possible. This loyalty cannot, however, be commanded; it must grow from a recognition of the qualities of leadership displayed by the executive, a leadership based on the possession of all the qualities of character previously mentioned in this section. If the employee feels a sympathy with the ambitious hopes that the manager holds for the company and is given an understanding of the methods by which the goal may be achieved; if he is sure that he will get a square deal based on a fair judgment of his merits and that his efforts will be rewarded by a

[2] Young, George J., *Elements of Mining*, p. 510.

word of appreciation as well as by more tangible advances in rank and salary—then the manager can count upon a vast reservoir of enthusiasm and co-operation that could not be purchased by any amount of money in a pay envelope.

Analysis of qualities.—In order to isolate from the qualities described above those that primarily make a capable executive, one may weed out those that would also be required by the most individualistic research worker that may be found in industry—a man working alone in a laboratory. Which of these qualities would not be needed by such a man? Scanning the list it becomes apparent that the only faculties that he would *not* require are: organizing ability regarding men (but not regarding materials), business instinct, understanding of human nature, fairness (although he would need mental honesty of the highest order), and the capacity to inspire loyalty. Such an analysis reveals, then, that the qualities that distinguish the executive from the other types of worker are concerned primarily with commercial skill and with relations between human beings.

A second perusal of the list will serve to throw light on the question: "Are good mine managers born or made?" It is immediately apparent that at least a trace of all the qualities noted are found in almost everyone. A greater preponderance of certain of these may be influential enough to dictate early in life the course through which a certain person will be impelled to seek his career: for example, the early appearance of certain traits may impel the engineer to believe that success for him will lie in teaching, or in selling, or in research. However, if the engineer decides when he is still a student that he will be most successful and happy in an executive position, and there is no insuperable physical handicap, it is likely that he can, by training and deliberate exercise, develop to the fullest extent his innate business and organizing instincts, acquire the sort of education that a manager must have, study human behavior on all occasions, and make an audit of his character traits at intervals to note any development. In brief, although some men are more predisposed than others to the commercial and executive life, there is no requisite quality for such a career that is entirely lacking in the average college student, and there is not one of these qualities but can be developed and strengthened by training and practice.

RELATIONSHIPS OF MINE MANAGER

The relations that the mine manager maintains with others are many and various, but in general they may be grouped into relations

with the board of directors, with his staff, with labor, and with others of the community.

Relations with board of directors.—When an engineer is about to be appointed manager of a property he should have the proposed power of attorney which he is to accept from the board examined by a good lawyer, one acting wholly in his interest. This lawyer should explain to him the full bearing of all the clauses and warn him of any pitfalls which may exist in, or embarrassments which may arise out of, the document. If he is also signing a contract for his services, the contract should be analyzed in the same way as the power of attorney, and care must be taken to see that the two documents do not conflict.

Not only should the manager himself refrain from "playing favorites" or giving jobs to incapables because they have some claim on him, but he should refuse to countenance such actions on the part of a director or important shareholder. "Perhaps one of the most common mistakes of mine managers," says Hoskins,

> is to submit to a condition of nepotism that is often furthered by directors or stockholders. No responsible position around a mine should be filled by a novice. Just because a director has two or three sons needing situations does not make it incumbent upon a superintendent or a manager to jeopardize his reputation by employing these young men. Percy Williams, a veteran mining man, advised: "Don't take your son or nephew or your clerk out of your store or business house and send him to Arizona or Colorado to run things for you at the mine. Sell out first. If you are a director in a mining company, do not force the manager or superintendent to find a job for all your unsuccessful friends and relatives. Let him hire his own men. Don't convert your mine into an asylum for ne'er-do-wells."[3]

Relations with staff.—Daily contacts with staff members and periodic meetings of the full staff every few days should be a part of the manager's generalship. It is preferable to hold these sessions at the general office, the clubhouse, or some other common meeting-place rather than at the manager's home.

The functional interrelationships of manager and staff are graphically presented in Figure 11 (p. 408). The isometric projection shows how maximal co-operation may be obtained in the routing of reports, conferences, supplies, and materials between the manager and each of his seven staff officers, and between any officer and any other officer. Of necessity, the chart does not attempt to show all possible relationships in a large and well-established staff; likewise,

[3] Hoskins, A. J., *The Business of Mining*, pp. 190–91.

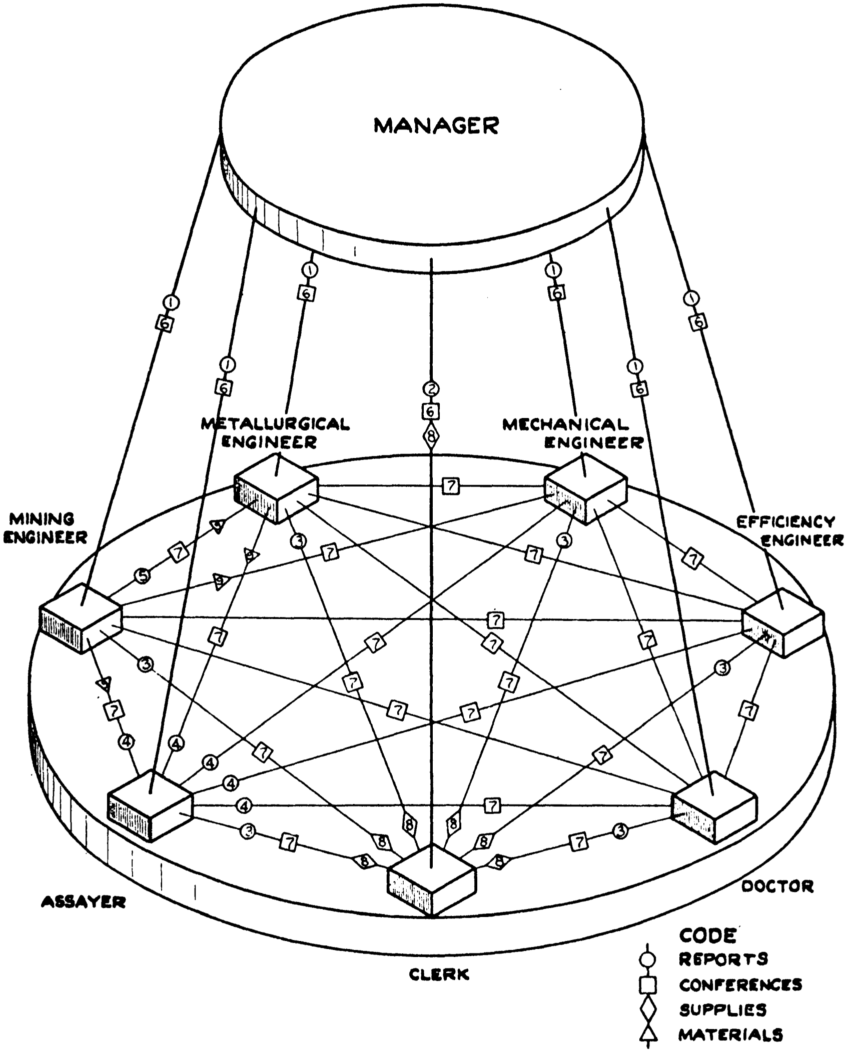

FIG. 11.—Functional Interrelationships of Manager and Staff

it would be confusing to show the many functional contacts which may exist between the staff officers and the various foremen, shift bosses, assistants, and workmen under their departmental supervision. It may be noted here, however, that—unlike the line-and-staff organization of a military force, in which an officer on one staff, such as the artillery, may issue orders to an individual of subordinate rank in another branch, such as the commissary—staff officers performing

one function may not interfere with the discipline of another department by issuing direct orders to subordinates.

Assuming that the mine organization will possess seven staff officers as shown in the chart, the network of relationships indicated by the figures inside the various symbols representing flow of reports, conferences, supplies, and materials may be itemized as follows:

Written reports. (○) Routine written reports will ordinarily appear on printed forms. Occasional special reports will require an interdepartmental letter or a memorandum to the interested person.

1. (Six times.)[4] Six of the seven principal officers should report in writing to the manager each day.

2. (One time.) The clerk is in such close contact with the manager that a formal daily report from him may not be needed; certain weekly or monthly reports or statements will, however, undoubtedly be required.

3. (Six times.) All of the other principal officers will submit written reports to the clerk, probably daily, concerning the time put in by the personnel of the various departments. This report may be made weekly, of course, and may be issued in the form of a timebook.

4. (Five times.) The assayer will issue certain daily reports to the mine superintendent and the metallurgist. He may also make chemical analyses for the mechanical engineer, the efficiency engineer, or the doctor.

5. (One time.) The written statement of the number of tons of ore sent from the mine to the metallurgical plant will pass every day from one to the other of the officers concerned, depending upon which has control of the weighing machine.

With the exception of items (3), (4), and (5) above, written reports from one staff officer to another need not be required in the ordinary routine. If one of the seven is co-operating with another on some special task it may be necessary for them to correspond; but under normal circumstances most department reports will be addressed to the manager.

Conferences and verbal reports. (□) Conferences, inspection tours, and other personal contacts among the staff members will be frequent.

6. (Seven times.) The manager will consult daily with his seven principal officers, probably both by telephone and in person. In addi-

[4] See corresponding figures within symbols in Figure 11.

tion to this, there should be a weekly meeting of the eight. If any important policy is decided upon at this meeting it should be recorded in a written minute, a copy of which is given to each officer; however, after the initial stages of organization have passed, such minutes will ordinarily be few.

7. (Twenty-one times.) Although certain officers must confer with each other more frequently than others, it is inconceivable that any of the seven will not on occasion have something of value and interest to discuss with each of the others, and therefore every connecting line on the chart surface is marked with a (7).

Supplies. (◇) Assuming that the clerk is at the head of the supply department, needed equipment of all sorts will be drawn from his office on requisition and charged to a departmental account.

8. (Seven times.) All of the staff officers, as well as the manager, will draw on the clerk for supplies in his charge.

Materials. (△) Materials, in the present instance, is taken to include ore, samples of ore, and waste rock.

9. (Four times.) Ore passes from the mine to the metallurgical plant, and as stated in (5) above will be reported on a written form; it may also be the subject of conference and discussion. Samples pass from both the metallurgist and the mining engineer to the assayer, and these will occasion written reports and perhaps also some consultation. Road metal may be furnished by the mine to the mechanical engineer.

The delegation of power and authority by the manager to his subordinates is seldom if ever made by a formal document, although it is preferable, in matters of importance, to put any extensive or intricate orders in writing. The duties of the staff officers are implicit in custom and tradition, or are derived by logical inference, and orders issued in daily discussions and directions grow in time to form a body of precedent which covers most of the ordinary routine duties at the mine. If the manager has supervised the growth of the mine from small beginnings and has properly trained his staff, the traditional methods of doing things should have become framed into a sort of code that will prescribe the required action in almost all contingencies. When an event occurs which is not covered by the code, the officer concerned will probably appeal to the manager for advice that will aid his decision; and so the code is enlarged day by day until it governs almost all possible cases. The manager's chief function, then, is to deal with exceptions to the rule; and thus one might state the paradox that the best manager is the one who

has least to do, since good management consists in building up a code of custom or habit in the organization that will leave a minimum of exceptions to be dealt with by executive decision. That this is true is shown by the example of those fussy managers who are daily deluged with a mass of routine details that leave them little time to outline plans for the future or to envisage the working of the organization as a whole; had these men made certain courses of action habitual among the members of the staff, they would always have time to perform their broader functions of guidance and co-ordination of the various branches.

Managers should not allow their interest in one or two departments of their work to cause them to concentrate on these departments at the expense of the rest. In the effort to attain certain small economies in a favored branch they may overlook the fact that great inefficiencies may be found in other branches and that these wastes, translated into terms of profit, may overbalance gains in other fields. In short, the manager should not spend all his time in the office, nor, on the other hand, should he give all his attention to the underground progress and neglect important matters having to do with the auxiliary services.

It may be well to repeat here that the staff officers derive no authority direct from the board of directors, and should have no contact whatever with the board except through the manager.

Relations with labor.—The position of the mine manager regarding labor has been stated by Herbert Hoover:

> In these days of largely corporate proprietorship, the owners of mines are guided in their relations with labor by engineers occupying executive positions. On them falls the responsibility in such matters, and the engineer becomes thus a buffer between labor and capital.

In many cases the interest of the management is identical with that of the other grades of employee in a company; while, on the other hand, many workers are also capitalists in the sense that they own corporate securities of various kinds and may even be shareholders in the company by virtue of some profit-sharing program. It is therefore difficult to draw strict lines between the three classes of capital, labor, and management. However, it is the responsibility of management as a professional group to see that: (1) the owners are rewarded by profits on their investment, (2) the workers are paid fair wages for their efforts, and (3) the public interest is served through low prices and social concord.

The demands of organized labor have been many and various, but they may be summarized in a sentence. What does the laborer want? Briefly, he wants a measure of security and steady employment, a fair chance for promotion and higher wages, healthful and cheerful living conditions for himself and his family, an opportunity to receive training that will advance him in his work, and, finally, some recognition on the part of the management of the importance of his place in the march of industry. These are not impossible goals, and it is the duty of the management to build up an effective organization by making every effort to insure the maximal realization of these hopes of the worker. No great efficiency can be expected from a group of dissatisfied human beings, at odds with each other and careless of the importance of their task. Labor, in order to be effective, must be directed to attain a maximum of co-operation, and the duty of leadership falls on the management. Further observations on the problems arising from the employment of labor form the subject of chapter 24. It should be noted that many men working underground do not desire promotion. Most big mining companies have difficulty in getting miners to accept promotion to the rank of shift boss and foreman.

The mine manager, then, cannot afford to neglect the human factor in industry. The men under him form a vital force that puts in motion the vast inert mass of machinery and materials through which production is accomplished and profit is made. The manager may be the best technician in the world, but if he is not capable of inspiring his subordinates to carry out their part in the scheme he and the company he represents are doomed to failure.

Some managers attempt to bolster up their authority by standing on their dignity and depending on the prestige of their august position to insure that their orders are carried out. But the title of manager has in itself no prestige greater than that created for it by the wise and energetic acts of the holder. A dignified attitude alone cannot get things done; authority accrues through a recognition by his co-workers that the manager is fitted for leadership and that his orders are based on a logical necessity. If the manager attempts to know all his men by name and to find out for what work they are best fitted, he need not fear that this will breed undue familiarity. Dignity is an empty word; *respect,* on the contrary, is dynamic.

The manager will be greatly assisted in his work of winning the respect of the personnel by the development of a good memory for names and faces. To do this, he need not subscribe to any of the

much-advertised "memory courses." Psychologists tell us that we remember only those things that we *need* to remember. In other words, one will not forget anything in which he is genuinely interested. For example, if a manager is casually introduced to a friend of a friend with whom he has no common interest and whom he never expects to see again, there is no real need to remember whether his name is Smith or Jones; but if Mr. Smith is the president of the company, the manager will not have to write down the name in order to remember it, nor will any roundabout mnemonic system be required to aid him to recall a fact of such great importance to him. He would *need* to remember Mr. Smith.

Another elementary rule of psychology will assist the manager in his human relationships: it is almost always within one's power to call forth the exact type of response that he desires. Human behavior under certain conditions is predictable. The response will depend primarily upon the attitude of the speaker—"do as you would be done by." Suppose that a difference has arisen between a manager and one of his subordinates. If he assumes a domineering and wrathful tone, he will call forth a like response, or else leave the other feeling that he is being unfairly treated and is entitled to whatever retaliation he can secure. If, on the contrary, he assumes an open-minded attitude of man-to-man discussion, and if the seriousness of the situation allows him any leeway of generosity, the subordinate is likely to come away with a strong impression of just treatment and a temporary difficulty will have been converted, by tactful handling, into a stronger bond of loyalty. If it can be shown that the act of the subordinate is justified by facts, the manager need not fear that he will weaken his authority by admitting that he was in error. Pretense of infallibility and arbitrary obstinacy will work far greater harm to an organization than will a frank admission that a mistake has been made.

Relations with community.—Aside from making agreeable business contacts with men of standing in the community, it is to be expected that the mine manager will assume the place in the social group to which he is entitled by the importance of his position. Since most mining towns are small and the residents are dependent upon each other for social life, many of them will look to the manager of an important mine property for leadership in this phase of human relationships. The manager may well take an active part in social affairs, providing, however, that his efforts do not lead to undue familiarities that would weaken his discipline, or to the possibility

of allowing social obligations to consume a disproportionate amount of his time or to prejudice his business judgment.

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Chapter 22

The Principles of Scientific Management in Mining

The term "scientific management" has a formidable sound. Yet in the last analysis it is nothing more than the application of the engineering method to industry with the intention of preventing waste and promoting efficiency in the use of men, money, machinery, and materials for the production of profit.

This revolutionary movement in industry developed late—the pioneer work of Frederick W. Taylor was reported in his paper on "Shop Management" before the American Society of Mechanical Engineers in 1903—but it has grown rapidly, until at the present time a large body of knowledge is available to students of this science.[1] It would be hopeless to attempt within the limits of a single chapter to summarize all the important contributions that have been made by writers on this subject. However, it will be possible to state the general principles on which is founded the art and science of management and to show how these principles may be applied to the reduction of wastes in the mining industry.

WHAT IS SCIENTIFIC MANAGEMENT?

The principles underlying present-day practice in scientific management have been well stated by Dr. H. S. Person, managing director of the Taylor Society:

1. Research in its various forms—the basic approach to a solution of the multiple problems of management.
2. Standardization—the specification of purposes, policies, plans, projects, facilities, and methods, as the relatively constant factors in terms of which plans may be made and their execution directed, measured, and appraised.

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[1] See Cannons, H. G. T., *Bibliography of Industrial Efficiency and Factory Management,* which contains approximately 3,500 references in this field.

3. Planning and control—the organization and direction of the application of facilities along predetermined lines for accomplishment of purposes, policies, plans, and projects.

4. Co-operation—recognition and acceptance of the laws governing managerial situations and discovered by research, formulated in standards and utilized in planning and control.[2]

The chief difference between scientific management and the old line type of supervision involves the complete reversal of the usual conception of organization, under which the board of directors appoints a manager and passes on responsibility to him, which he in turn passes on to his subordinates, until at the bottom of the organization the individual workmen bear the whole responsibility of efficient performance. This system of "passing the buck" to the laborer—who has the least time, executive training, and educational advantages to dictate the trend of activity—produces an organization directed from the bottom instead of the top and one which is only as strong as its weakest link. It should be replaced by a conception of organization whereby the responsibility is placed where it belongs: the foreman should be on the job, not to relieve the superintendent of responsibility, but to direct, assist, and instruct the workman to perform his task in the most efficient way. Similarly, the general manager should exist for the sake of the superintendents, and the president and the board of directors for the sake of the manager. It then becomes the duty of these officers first to discover how they can best assist their subordinates to carry out administrative policies with maximal efficiency, and to state these findings objectively; and, second, to apply the results of such research to the living organization. The process of planning for economy and setting up standards of performance may be termed "efficiency engineering"; the process of carrying out the plans and achieving the designated standards may be termed "supervision." Since it is impossible for a single executive to perform all the complex duties entailed in both branches, the old line type of organization must be replaced, under scientific management, by a staff charged with the various functions of planning, research, routing, discipline, selection of personnel, wage-setting, and direct supervision, in order best to assist the individual laborer in the efficient performance of his task.

[2] Person, H. S., "Principles and Practice of Scientific Management." A paper delivered at the World Social Economic Congress, Amsterdam, 1931.

Growth of the management movement.—The application of scientific method to increase the efficiency of the human units in industry has already wrought in many fields a new industrial revolution as great as that resulting from the application of power machinery at the end of the eighteenth century. The movement began in a practical way in the shops of the Midvale Steel Works at Philadelphia, where Frederick W. Taylor, working as a foreman, began to study scientifically the performance of various industrial tasks by human units. He perceived that there is one best way of doing any specific task—that there is, in his words, a "science of shoveling"—and that it is the duty of management to enable the workman to realize his potential powers to the fullest extent by fitting him to the right job and by teaching him the method that has been found, by means of time-studies and other experimental techniques, to be most efficient and most in accordance with the aims of the administration.

Taylor knew that a man is something more than a machine, however, and placed most emphasis upon the contributions of management toward lightening human toil, improving the conditions of labor, lowering prices, and bettering relations between employer and employed. The most obvious benefit of his system—the lowering of production cost—was, however, unfortunately seized upon by employers and self-styled efficiency experts who disregarded his warning and attempted to apply his revolutionary methods in wholesale fashion without undertaking the long and delicate program of educating the workmen to the advantages which would come to them through co-operation. Taylor devoted his life to advancing his philosophy and combating the misunderstanding of his method by those to whom the time-study was repugnant as the symbol of a new form of slavery. His associates and followers—Gilbreth, Gantt, Barth, Sanford E. Thompson, Emerson, Going, and others—carried on the work of developing the principles and applying them in various fields, and did much to offset the ill-advised and abortive attempts of "experts," who sprang up overnight when public interest was at last aroused and efficiency became the slogan of the day, seeking to plaster a superficial management method on an industry without performing the necessary preparatory research and without forcing a complete revision of the old concepts of management. Although such attempts made the term "efficiency expert" one of derision, the new principles of management were widely applied, until scientific management, specialization of function, and scheduled

mass production have become the outstanding characteristics of American industry.[3]

Management and the future.—The application of science to the invention of mechanical devices for supplanting human muscles and to the reorganization of the machinery of business has within a few decades made it possible for a modern industrial nation to produce more goods, including metals, than it can usefully consume. Profit in the form of goods and credits has been piled up through these means; unawares, we have passed from an economy of scarcity into an economy of abundance. But there is no reason why, on these grounds, we should relax our efforts toward efficiency or abandon the gains that have been made by applications of the scientific method to production. On the contrary, it now becomes possible to make available to greater numbers of citizens the fruits of profit in the form of heightened standards of living, greater leisure, economic security, and increased opportunities for happiness. The problem of efficient production is well on the way to ideal solution; the problem of distribution of profits for the general welfare, which has in the past few years set before the world with a cruel pointedness the evils of an unmanaged economy, is still to be faced. Under the present order, wastes in distribution and consumption may heavily offset gains made in the efficiency of production. The antiquated doctrine of *laissez faire* encourages the production of any goods which may be expected to return a cash profit to the producer; it occurs to few that the process should be reversed: that men should first determine what goods the community, as a consumer, should reasonably be furnished, and then should set about producing these goods in proper amounts. Once a correct ideal in the distribution of profits has been erected, however, this problem, like the problem of production, can be resolved through human co-operation, and by means of the *same principles of planning and scientific management.* This line of reasoning applies with special force to the mining and metallurgical industry.

[3] "Scientific management has sometimes been confused with the division and specialization of labor, and with mass production—both of which are fundamentally different. Adam Smith (1723–1790) described in his *Wealth of Nations* the division of labor and also mass production in the making of pins by hand. This same principle now made use of in the abattoir processes, and in the manufacture of automobiles, is sometimes erroneously called *scientific management,* though it frequently is combined with highly scientific management methods."—*Encyclopaedia Britannica,* Fourteenth Edition, article "Scientific Management."

Modern civilization has been builded through the activities of the engineering type of mind, and it is to this same type of mind that the world must turn for the larger management and reorganization of a technological society. The treatment must be homeopathic. The rationalization of the social organization will be performed by the engineer-economist, who will approach the problem with the same method that he has used in solving purely technical problems. He will not proceed on the basis of preconceived dogma; he will not be led astray in the quest of lightning panaceas; but he will study scientifically the social order and advance through experiment, trial, rejection, and selection, revising his theories in the light of new facts. He will not be misled by labels, but will look beneath them and weigh the intrinsic factors without blindness. He will not, therefore, be horrified by any idea merely because it is new; nor will he shy like a frightened horse from an idea around which has grown an aura of prejudice; nor will he fall into the error of confusing two ideas merely because they bear the same name, or, on the other hand, of failing to recognize that two things with different names are intrinsically the same. In short, he will apply the method of integration and the principles of efficiency to problems in which the human factor is predominant.

Already a beginning has been made toward realizing Veblen's vision of an economic order controlled by the trained manager:

> In effect, the progressive advance of this industrial system towards an all-inclusive mechanical balance of interlocking processes appears to be approaching a critical pass, beyond which it will no longer be practicable to leave its control in the hands of business men working at cross purposes for private gain, or to entrust its continued administration to others than suitably trained technological experts, production engineers without a commercial interest.[4]

It is easily conceivable that such a new order may grow logically and legally under the present form of government. Although outworn concepts may undergo drastic modification, there is nothing in the Constitution of the United States to bar the reorganization of political functions to fit a modern technological society, without recourse either to dictatorship or to red revolution. There are other revolutions than those of torch and bayonet, however—the heavy-handed application of income and inheritance taxes would probably have been more shocking to the fathers of the Republic than would bol-

[4] Veblen, Thorstein, *The Engineers and the Price System*, p. 58.

shevism. But whatever the ultimate form of rational organization through which national waste and inefficiency are to be overcome and the gap between production and consumption is to be bridged, there is no doubt whatever that the men who will do the work must be engineers. No other group has the education and experience derived from first-hand contact with the problems, and rigid training in religiously following the fact method. This is what H. G. Wells means when he speaks of "open conspiracy,"[5] and what is implied by Stuart Chase when he pictures the growing consciousness of the engineer of his place in a technological society:

> At the control switches of the nation stand perhaps one hundred thousand technicians—engineers and operating managers—responsible in the last analysis for the food and the very lives of one hundred and twenty million people. If they should all desert the controls for as much as a few hours we should be done for. These men have an altogether realistic perception of cause and effect. They must have. Neither mysticism, political rhetoric, nor contemplation of the navel will get kilowatts out of Niagara. Increasingly they are becoming aware of their importance in the scheme of things. I have talked to scores of them who already know what an economic system is for.[6]

It is possible that the activities of the human population of the globe may be ultimately regulated, as envisioned by Kipling,[7] by a handful of engineers.

The greatest hope for a speedy readjustment of the economic disturbances of the world is the fact that engineers everywhere are becoming increasingly cognizant of the need for orienting themselves among the larger problems of human existence and are thinking beyond the narrow, specialized limits of purely technical details. The engineer of today is devoting himself wholeheartedly to broadening his own education and to planning that succeeding generations of engineers will be given the enthusiasm and training necessary for an effective participation in the creation and control of an efficiently conceived and operated human society, which will insure that a given effort will commensurably increase the modicum of average individual comfort and happiness; and of basic importance in this increase of comfort is a continuous and adequate supply of metals.

[5] *The Work, Wealth, and Happiness of Mankind,* Vol. 2, pp. 855–67.

[6] Chase, Stuart, *A New Deal,* p. 177. Quoted by permission of the Macmillan Company, publishers.

[7] Kipling, Rudyard, "As Easy as A. B. C.," *A Diversity of Creatures.*

THE TAYLOR SYSTEM IN ACTION

A concrete example of the methods used by scientific management to attain maximal efficiency in a task familiar to all mining engineers may be presented by briefly describing one of Taylor's earliest efforts, as depicted in his book, *The Principles of Scientific Management*—a classic which will be read with interest by anyone concerned with efficiency engineering.

The art of shoveling.—It is strange to think that until Taylor began his work at the Midvale shops apparently no one during the centuries of human labor had thought to discover, state objectively, and standardize the best method of performing any one of the thousands of industrial tasks. Skilful artisans, in the course of their work, might effect better methods, but these methods were jealously kept secret, and each apprentice had to start from the beginning and rediscover his trade. If a surveyor, instead of being taught the accumulated knowledge of the centuries, were to be educated under such a plan, he would be forced to work out, from his own experience, all the propositions which Euclid solved for him 2,300 years ago. Taylor, convinced that every single act of a workman can be reduced to a science and taught him by the management, set out to study the elements of some of these small but important tasks in an attempt to reduce time and effort to a minimum.

At the works of the Bethlehem Steel Company, where he was employed, Taylor began to make a series of experiments to determine how the "science of shoveling" might be applied to the force of some six hundred laborers doing this class of work in the yards. The first question that came to mind was: What is the shovel load at which a first-class shoveler will do the biggest day's work? By scientifically observing the work of two or three men, carefully selected and paid extra wages for faithfully carrying out the directions of the observer, it was found that this load is about twenty-one pounds. As a result of this discovery, instead of allowing each laborer to use his own shovel, the company supplied some eight or ten different types of shovels, each scientifically suited for use at a particular task. This made it possible to issue to each workman a shovel which would hold a load of twenty-one pounds of whatever class of material he was to handle; a small shovel for heavy ore, for example, a large one for ashes. If a single shovel were used for both materials the worker handling ore would be so overloaded that it would be impossible for him to do a full day's work, while if he

were handling rice coal, say, he would be ridiculously underloaded, for the shovel could hold less than four pounds of this material.

This simple expedient was merely one of several modifications which came as a result of thousands of stop-watch observations on such variables as the comparative time required in shoveling different materials, the effect of shoveling on dirt bottoms and wooden bottoms, the distance through which the load is carried, and the frequency of rest periods to minimize fatigue. When standards for each type of work were established and the best practice was slowly and tactfully taught and applied, it then became necessary to organize the work of shovel gangs in order to eliminate loss of time through waiting and through uneven distribution of men at different places in the yards. Each man, however, was treated as an individual, and every part of his work was planned well in advance by a central office. A definite and unvarying task was set for each man each day, and each day he was given a piece of paper which stated just what implements he was to get from the tool room and where he was to start work. He was also given a statement of the work he had done the day before.

> Many of these men were foreigners and unable to read and write, but they all knew at a glance the essence of this report, because yellow paper showed the man that he had failed to do his full task the day before, and informed him that he had not earned as much as $1.85 a day, and that none but high-priced men would be allowed to stay permanently with this gang. The hope was further expressed that he would earn his full wages on the following day. So that whenever the men received white slips they knew that everything was all right, and whenever they received yellow slips they realized that they must do better or they would be shifted to some other class of work.[8]

If a workman failed to do his allotted task, a competent teacher was sent to guide and encourage him, thus giving him the time and help required to make him proficient at his job, rather than brutally discharging him or lowering his wages for failing to make good at once.

This system of selection and training built up within a few months a fine body of men, accustomed to performing their task easily and effectively, and having a high morale resulting from the knowledge that they were being taught by a friendly management to earn higher wages and from a feeling that they, as individuals, were fitted to their jobs and were performing an honest day's work. "It would have been absolutely impossible for anyone to have stirred up strife between these men and their employers." Taylor adds:

[8] Taylor, Frederick W., *The Principles of Scientific Management,* pp. 68–69.

All of this requires the kindly co-operation of the management, and involves much more elaborate organization and system than the old-fashioned herding of men in large gangs. This organization consisted, in this case, of one set of men, who were engaged in the development of the science of laboring through time study, such as has been described above; another set of men, mostly skilled laborers themselves, who were teachers, and who helped and guided the men in their work; another set of tool-room men who provided them with the proper implements and kept them in perfect order; and another set of clerks who planned the work well in advance, moved the men with the least loss of time from one place to another, and properly recorded each man's earnings, etc. And this furnishes an elementary illustration of what has been referred to as co-operation between the management and the workmen.

That such a functional organization is not top-heavy and can be made to pay for itself is shown by a statement[9] of the results of the third year of working under the plan:

	Old Plan	New Plan Task Work
Number of yard laborers	400–600	140
Average number of tons per man per day	16	59
Average earnings per man per day	$1.15	$1.88
Average cost of handling a ton of 2,240 pounds	$0.072	$0.033

In computing the lowered cost of $0.033 per ton, the office and tool-room expenses, and the wages of all labor superintendents, foremen, clerks, time-study men, etc., are included. During this year the total saving of the new plan over the old amounted to $36,417.69, and during the six months following, when all of the work of the yard was on task work, the saving was at the rate of between $75,000 and $80,000 per year.

Summary of Taylor system.—An examination of the foregoing example, and other applications of scientific method to industrial tasks as cited by Taylor, bring out the following characteristics of Taylor's system:

1. The development by the management of a scientific method of performing each task, and the standardization of practice, tools, and working conditions.
2. The scientific selection of first-class workmen, fitted in every way to perform their duties.
3. The friendly training of the first-class workman to teach him the scientific performance of his task and to develop his capacities to the utmost.
4. The treatment of each worker as an individual, who is expected to perform a given task in a given time, and who will be daily informed of his success or failure to attain the standard.
5. Increased wage reward for increased efficiency.

[9] *Ibid.*, p. 71.

6. Use of proved labor-saving devices.
7. Functional control by a number of foremen charged with various duties of supervision.
8. A planning department to control the application of labor, route the work, and issue instruction cards.
9. Assumption by the management of full responsibility for the above program, and for encouraging intimate and friendly co-operation between workman and management.

It should be noted that Taylor's chief efforts were directed toward improving the status of the workman, rather than toward attempting heartlessly to sweat him or narrow him into a machine-like drudge. The installation of his system, he pointed out, should be undertaken by a slow process of educating a few selected men at a time; no time-studies were to be carried on without the full consent of the worker. Again, teaching better methods and the use of improved tools leaves the workman free to make use of his own originality and ingenuity to make real additions to the world's knowledge, instead of reinventing things that are old.

> What really happens is that, with the aid of the science which is invariably developed, and through the instructions from his teachers, each workman of a given intellectual capacity is enabled to do a much higher, more interesting, and finally more developing and more profitable kind of work than he was before able to do.

And, finally, he points out that:

> The mechanism of management must not be mistaken for its essence, or underlying philosophy. Precisely the same mechanism will in one case produce disastrous results and in another the most beneficent.

The development of a humane and farsighted philosophy of administration must precede the application of the Taylor mechanism of scientific management.

The Taylor system in mining.—The Taylor system is best adapted for factory operations where the same process is repeated continually under the same conditions, and is not particularly adapted for mining work where, as in breaking ground, the conditions are continually changing. It has, however, been used in the Lake Superior copper mines with some success.[10] For such operations as hand tramming and shoveling it seems better adapted, and good results were obtained in a study of shoveling at the mines of the Phelps-Dodge Corpora-

[10] McDonald, P. B., "Efficiency Engineering in the Copper Country," *Min. Sci. Press*, July 24, 1915, pp. 120–21.

tion at Tyrone, New Mexico, where the tonnage handled was raised from 8.5 to 22.9 per man and the cost reduced from 33 cents to 24 cents per ton, while the wages were increased from $3.40 to $4 per shift.[11] In place of the rigid Taylor system, the more flexible Emerson plan seems better adapted to mining.

THE EMERSON PRINCIPLES OF EFFICIENCY

Harrington Emerson, a follower of Taylor, carried Taylor's observations beyond mere methods and logically concluded that there were certain principles of scientific management which could be applied to any situation requiring human co-operation. Although it is generally supposed that Taylor and Emerson represent two entirely different systems, it is more reasonable to consider the work of Emerson as an outgrowth and generalization of his predecessor's studies. Emerson's system concerns itself, one may say, with the strategy of management rather than with its tactics. There is also another difference, in that, although both believed that the various duties of management should be functional, Taylor assumed that these duties could be performed by a group of line officers of military type, while Emerson preferred to turn them over to staff officers serving—except for a few supervisory production officers—in a purely advisory capacity.

Comparison of Taylor and Emerson systems.—The two systems have been excellently contrasted by Charles B. Going:

> The Taylor system displaces ordinary management by the introduction of a highly specific, distinctly defined "functional force." The performance of work is first divided into two phases—planning and execution. Each of these phases is separated into four major functions. The four functional representatives in the planning department are "the order of work clerk," "the instruction card man," "the time and cost clerk," and "the shop disciplinarian." The four functional representatives in the active work of the shop are "the gang boss," "the speed boss," "the inspector," and "the repair boss." There may be one or many representatives of each function, depending upon the frequency with which their function necessarily brings them in contact with the men: but within any one function, the workman looks to the particular boss of that function for his orders and assistance. The workman takes orders from eight different bosses instead of from one only as under the ordinary system of management. The details of the system are also highly specific, as, for example, that all work, tools, and equipment

[11] Harley, G. T., "A Study of Shoveling as Applied to Mining," *Engin. Min. Jour.*, March 15, 1919, pp. 481–85; March 22, pp. 520–23.

parts are symbolized, the performance of every operation is charted, all instructions are written, etc. The salient feature, however, is that the old line organization be discarded, and eight functional lines are put in its place.

Emerson leaves the old line intact, but supplements it with an expert staff, who bring to bear highly specialized knowledge and skill upon the various elements of operation that are susceptible to improvement. These might be, for example, such matters as the economical burning of fuel, the custody and issue of materials, the cutting of metals, the care of machinery and equipment; these are random illustrations only. The staff organization would be specialists in the subjects of largest influence upon economy of operation, but their knowledge would be applied, not by direct orders to the workmen, but by guidance, instruction, suggestion, counsel, to the regular line officials. Emerson's faith is not in methods, but in principles of efficiency and their pursuit by a line-directed and staff-guided organization, adapted to the circumstances and conditions of any given operation.[12]

Principles of efficiency.—Bearing in mind that efficiency is the application of available resources with a minimum of friction and waste, it now becomes possible to consider the twelve basic principles laid down by Emerson, briefly indicating how each may be applied to the industry of mining.

Emerson's principles, as enunciated in his book, *The Twelve Principles of Efficiency,* are as follows: (1) Clearly defined ideals, (2) Common sense, (3) Competent counsel, (4) Discipline, (5) The fair deal, (6) Reliable, immediate, and adequate records, (7) Dispatching, (8) Standards and schedules, (9) Standardized conditions, (10) Standardized operations, (11) Written standard-practice instructions, and (12) Efficiency reward.

Although these general ideas are specifically drawn from observations of industrial enterprises, they hold good for increasing the efficiency of any human organization for performing a given task—such, for instance, as the waging of war by an army. Most of the principles may also be self-applied by an individual to heighten his personal efficiency.

It will be noted at once that the first five principles are of a sort entirely different from the remaining seven. Of this Going says:

> From a wholly material, non-moral, and near-visioned point of view, indeed, the seven "practical" principles alone would be sufficient for the achievement of success. Even an evil purpose can be most effectively accomplished by their observance. When, however, these are interlocked with the five "altruistic" principles, purposes, as well as measures, are turned from lower temporary desires to the larger eternal desirabilities. The doctrines

[12] Going, Charles B., *Principles of Industrial Organization,* McGraw-Hill, pp. 147–49.

of efficiency therefore define something infinitely greater than a system of management.[13]

For the present purpose, however, it may be more useful to divide these principles on the basis of a subdivision of scientific management proposed a few pages previously, and to consider the first five principles as relative to the problems of administration and supervision, and the remaining seven as relative to the methods of efficiency engineering.

1. *Clearly defined ideals.* The administration of any business should at all times have in mind the goal at which it is aiming. Such an ideal furnishes the ultimate measure by which every company policy may from time to time be tested. "If a man does not know to what port he is steering," said Seneca, "no wind is favorable to him." It is impossible to achieve a number of goals, some of which may conflict with others, and therefore the chief purpose of every organization should be steadily kept before every member of the group. A proper ideal for a mining and metallurgical company would be the production of metals for the use of the human race at the lowest cost compatible with (*a*) the minimum of waste of natural resources and (*b*) a reasonably high standard of living and welfare for all employees.

It should further be remarked that ideals should be within the bounds of attainment, and should logically fit in with the needs of all existing social, political, and economic conditions. One reason why the ton-mile cost on American railways is about half that on the average English line is that, at the beginning of construction, British engineers set themselves such rigid standards of grade, curvature, and double trackage as to double the capital cost of their railways and forever curtail their capacities.

2. *Common sense.* Broadly speaking, all scientific management is merely applied horse-sense. Innumerable examples might be cited from the field of mining wherein costly and over-ambitious engineering projects might have been prevented had the scheme been subjected to the test of practical needs. The most outstanding deficiencies in this regard are shown, perhaps, by widespread overcapitalization and over-equipment. American megalomania, preoccupation with bigness, has been responsible for the fact that there is hardly an industrial plant in the United States that uses all its equipment to its fullest capacity. Putting the cart before the horse, by constructing

[13] Emerson, Harrington, *The Twelve Principles of Efficiency*, Introduction.

peak-load plants years before peak production is reasonably assured, is responsible for the waste represented by rusting mining and metallurgical plants scattered throughout the country, deserted when the delusive hopes of the producers were not realized. A generous handful of common sense is an indispensable ingredient to production planning, as it is to all other applications of the engineering method.

3. *Competent counsel.* It is impossible for one man to attain expert knowledge of all subjects upon which he is called to make decisions. It is therefore of great value to a mine manager to have the ability to select competent advisers whose reports will give him the necessary facts upon which to base his judgment. The responsibility, however, is in the end always his alone. Competent counsel does not always follow from the employment of university-trained men; they must have had experience to supplement their education. Competent counsel does not always follow from the employment of reputed experts; the expert may grow lazy or careless. Competent counsel does not always follow from the employment of high-salaried men: a man may build up a reputation by great achievements, and with increasing prosperity and the multiplication of cares he may delegate more and more of his work to inexperienced and incompetent assistants—the result being disaster which involves his employer in loss and himself in damage to his reputation. The manager or president of a large mining or metallurgical company who trusts implicitly to the wisdom and capabilities of his subordinates is courting disaster. He alone is in a position to co-ordinate all sources of knowledge and to decide how these factors may work upon each other and influence the general situation. Competent counsel will ordinarily be called for in applying every one of the other eleven of Emerson's principles.

4. *Discipline.* The advance of civilization is always accompanied by an increased need for discipline—not the arbitrary tyranny of primitive rule by taboo and mandate, but co-operative and organized striving toward a definite goal, guided by trained and selected leadership. The almost incredible achievements of modern science and industry are the result of disciplined action on the part of countless millions of men and women working co-operatively.

The most effective discipline cannot be imposed from without. The most powerful dictator cannot long maintain his order unless the great majority of the members of his organization are in sympathy with his aims and are willing to impose upon themselves the restrictions necessary for efficient action. Real discipline springs

from the *esprit de corps;* the displeasure of a superior officer is of less account to a worker than the feeling that he is not in accord with the spirit of his fellows, that he is not a part of a group working loyally for a common end. The manager should therefore strive to build up a body of workers imbued with loyalty to his leadership and willing to discipline themselves in return for the advancement and reward that come from meritorious service. Says Emerson:

> No man ought to be allowed to enlist who cannot start in with order, enthusiasm, loyalty, reliability, who is not courteous and decent; no man ought to expect to stay who is not competent, a good brainworker, honest, economical, and diligent.[14]

The discipline of a mine staff should be just and mild, but inexorable. Under the best management there are scarcely any rules and few punishments. Instead, there are standard-practice instructions, so that every man may know exactly what is his part in the game; standardized conditions and standardized operations are established; definite responsibility is secured by reliable, immediate, and accurate records of everything of importance; and there are tangible efficiency rewards. So long as a man adheres to the established plan he is in no danger of penalties; but the instant he departs from the standard the whole weight of discipline should fall on him.

5. *The fair deal.* The final supervision principle is termed by Emerson "the fair deal." When an issue has been scientifically studied and resolved into its elements, so that the points are clear in the minds of all, an appeal to the sense of fair play that every human being possesses in greater or less degree is usually more successful than any recourse to force. The point is, however, that this principle cannot be applied until the preliminary study has been made and presented in unequivocal terms. In other words, administrative action making use of the fair deal must be preceded by an application of the principles of efficiency engineering. Such a study may show by incontrovertible fact that the first impulse of a manager intent on giving fair treatment may in truth work contrary to his intentions and prove harmful to the workers he sought to benefit. For example, he may wish to increase efficiency by paying high wages; if these wages are too high, however, he may defeat his purpose. This may be demonstrated by quoting from Taylor:

> A long series of experiments, coupled with close observation, had demonstrated the fact that when workmen of this caliber are given a carefully

[14] Emerson, Harrington, *op. cit.*, p. 162.

measured task, which calls for a big day's work on their part, and that when in return for this extra effort they are paid wages up to 60 per cent beyond the wages ordinarily paid, that this increase in wages tends to make them not only more thrifty but better men in every way; that they live rather better, begin to save money, become more sober, and work more steadily. When, on the other hand, they receive much more than a 60 per cent increase in wages, many of them will work irregularly and tend to become more or less shiftless, extravagant, and dissipated. Our experiments showed, in other words, that it does not do for most men to get rich too fast.[15]

It is a question whether the high wages paid to labor during the period of America's participation in the World War and during the boom of 1928 did not put a premium on inefficiency and lead to extravagance and dissipation.

It is merely a matter of common sense for the management to assure a worker's efficiency by making his working and living conditions safe and healthful. Says Emerson: "A locomotive or other machine is cleaned, housed, kept in repair, given good fuel and good water because its efficiency is thus increased; and in the interests of plant efficiency men should be treated at least as well as we treat machines." Few mine managers can be found who will controvert the statement that any expense for good ventilation, lighting, potable water, moderate working hours, and general welfare will more than return their cost in increased efficiency. It is yet to be generally understood, however, that efficiency-engineering studies can yield even greater savings by selecting the right man for the job, by training him to make the most of his abilities, and by devising methods for allotting him the proper wages for his work. The waste involved in the reckless hiring and firing of the unfit shows how the fair deal can be applied to personnel problems and industrial relations.

The horrible injustice lies not in establishing equivalency between pay and performance, which is as elemental as having accurate and certified scales in measuring the weight of what is sold or bought, but in retaining a man, whether by employer or by union, in a position to which he is constitutionally unadapted and for which he is unfit.[16]

The conspicuous absence of the fair deal in many instances of industrial friction is based primarily upon the fact that none of the parties has sufficiently investigated the underlying terms of the problem and has therefore been unable to discover wherein lie the

[15] Taylor, Frederick W., *The Principles of Scientific Management*, p. 74.
[16] Emerson, Harrington, *The Twelve Principles of Efficiency*, p. 180.

best interests of all parties. The principles of efficiency engineering, application of which may do much to remove the cloud of ignorance surrounding most disputes of this sort, will now be discussed.

6. *Reliable, immediate, and accurate records.* The first requisite for efficiency in any organization is the establishment of a system of reliable, immediate, and accurate records, to aid the memory of those performing work and to serve for the information of others concerned. Such records not only give a history of what has been performed in the past but furnish a basis for the establishment of standards and for planning future activities intelligently. A great number of records, varying from the time-card of a workman to the annual company report, are used in mining; the number of different records will ordinarily increase with the size of the organization.

Records may be source records, made on the spot from first-hand observations, such as time-sheets, tonnage reports, inventories, time-studies, medical examinations, field notes, and the like; or they may be secondary recapitulations, charts, tables, or statements based on source records and compiled for a particular purpose. Cost-accounting sheets, efficiency reports, supply cards, financial statements, progress reports, payroll sheets, and production charts are examples of secondary records.

A common administrative error is to lose sight of the fact that records should always be compiled with their particular purpose clearly in mind. Too often the routine of gathering records becomes stereotyped and their compilation becomes an end rather than a means. The test that may be applied to the installation or retention of any record system not required by law is whether or not the gain or saving resulting from use of the records will pay for itself. Cost-accounting figures, for example, may attain such elaborate proportions as to add appreciably to operating cost and thus defeat their sole purpose.

The typical forms of reports exchanged among staff officers are shown in Figure 11, page 408. The various kinds of records employed in mining, and their uses, are further discussed in chapter 23.

7. *Dispatching.* Dispatching is the principle aiming to eliminate waste of time and resources through the control of movements by a centralized plan, so that all activities of the various units are coordinated into one smoothly operating program. "Measure not dispatch," said Francis Bacon,[17] "by the time of sitting but by the

[17] *Essayes or Counsels Civill and Morall,* Essay XXV, "Of Dispatch."

advancement of the business. . . . . For time is the measure of business, as money is of wares." A conspicuous example of the elimination of lost time and the establishment of a rhythmic and habitual flow of activity is, of course, the dispatching of trains on a railway line. This was the highest degree of dispatching attained in America until its entrance into the World War, when a complete program of operations concentrated on a single purpose and co-ordinating all units of the machine rendered possible the successful issue of the military operations of 1918.

Although dispatching cannot be applied to the mining industry with the same thoroughness as to the operation of railways, its application to mining and metallurgical organizations is fundamental to efficiency. No worker should lose time or waste effort because of a hitch in the schedule—in waiting for supplies, waiting for repairs which should have been foreseen, waiting for arrival or removal of ore, or the like. Many mine managers have taken over their dispatching schedule—or scheme of hourly, daily, and monthly operations—from their predecessors without thought of improving it in whole or in part. In attempting to speed the operations of any organization, discipline and application of the fair deal must be extended; new ideals of order, promptness, and economy may have to be instilled; common sense will need to be exercised; complete record systems will certainly be required; competent counsel should be engaged; and perhaps others of the efficiency principles will need to be reapplied.

8. *Standards and schedules* (*research*). The first step in determining the efficiency of a machine or a human being or organization is to measure its performance in quantitative and qualitative terms. Efficiency is the ratio of work output to energy intake. This cannot be expressed until both the type and amount of work produced and the energy consumed can be stated and the standard efficiency for each type of machine or each individual discovered. The attempt to measure average efficiency and to invent new methods by which it may be increased is what Emerson means when he speaks of "standards and schedules." Since his day this branch of industrial study has expanded a thousandfold, and under the appellation "research" has become one of the chief departments of management. It is at this point that the time-motion experiments of Taylor assume prime significance among the principles of efficiency. It is interesting to note that Taylor's studies of man-efficiency led him to work in the field of material-efficiency, as is shown by his invaluable contribution,

in collaboration with Maunsel White, to the development of high-speed cutting steels.[18] The place of research in a mining and metallurgical company is dealt with in the following chapter.

9. *Standardized conditions.* Man progresses only when he is able to conquer his environment in greater degree, to bend unwilling nature to his purpose. In order to promote efficiency the conditions of work which have been shown by research to be the best should be unvarying and should be familiar to every worker, who thus can know what to expect and can depend upon habitual schedules and standards. Working conditions should be as safe and comfortable as possible, so as to impose no undue fatigue or danger to health. The layout of the plant, above ground and below, should be planned to obtain maximal economy of movement. The daily production load should be neither too light nor too heavy, as one brings idleness and the other wasteful strenuousness. Supplies and tools should always be obtainable at one designated place, as conveniently near the working-places as possible. Emergencies may arise which temporarily disarrange the usual program, but such exceptions should be reduced, by careful dispatching, to a minimum, and the standardized conditions should be restored as quickly as possible.

10. *Standardized operations.* Standardization of operations is also a part of the efficient performance of work. All important tasks, after research has indicated the most suitable method of performance, should be standardized and invariably performed in the same manner. Drill makes such methods habitual and leads closer to ideal maintenance of a standard dispatching schedule. Such standardization not only increases production, but leaves a margin of time and energy to deal with unconformable incidents which are bound to arise.

11. *Written instructions.* Written records to communicate information and to aid the memory act, in Emerson's metaphor, as a sort of ratchet; the mind can advance from them, but can never slip back below them. Written instructions are widely used—in government, army and navy, business, law—and should direct the performance of even the most minor operations in mining practice. "Each one of the ten preceding efficiency principles can and should be reduced to written, permanent standard-practice instructions, so that each may understand the whole and also his own relation to it."

[18] Taylor, Frederick W., and White, Maunsel, "On the Art of Cutting Metals," *Trans. Am. Soc. Mech. Engin.*, Vol. 23 (1906).

The approved method of performing a task can be codified and taught in this manner. Whenever one undertakes to record current practice in any plant, a great many contradictions and absurdities are sure to appear, which can then be amended. In short, written instructions are the growing and visible law of a mine or metallurgical plant.

12. *Efficiency reward.* It is obvious that meritorious observance of all the preceding principles should be recognized by a prompt and tangible reward, in a form most likely to spur further efficiency and to increase loyalty to the administration. If a man has done a good day's work he should know immediately that he has earned a good wage; if he fails he should know at once in what amount he has fallen short of the standard. Special service or valuable suggestions for improving conditions should meet with special recognition. Several methods of reward for faithful performance of labor will be mentioned in chapters 24 and 25.

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Chapter 23

Efficiency: Research, Analysis, Planning

Increased efficiency in mine operation may be attained by the management through application of the principles of the engineering method described in chapter 1. Greater profits may be won by either or both of two means, increase in production, or reduction in costs; and these in turn may be secured through an organized program using the three engineering processes of (1) research and fact-finding, (2) analysis and presentation of these facts, and (3) synthesis of all pertinent factors to enable logical planning for efficient operation and to formulate administrative policies for the guidance of the supervisory staff. It is the business of the efficiency engineer, working under the direction of the mine manager, to take the initiative in applying this program to all branches of the company's activities.

It will be noted that the seven "practical" principles of efficiency in Emerson's list (see above, pp. 426–27) fall within the scope of the present chapter. Since Emerson's day the fields of industrial engineering and scientific research have grown to assume tremendous importance in increasing the range and efficiency of industry; the use of records, standardized operations, and other such topics have each formed the subject of an immense body of technical literature, and many new openings for industrial research have become apparent. Almost every industrial operation has been scrutinized to see if some improvement could be made in the interests of efficiency; new techniques have been invented for observing, recording, and presenting facts bearing upon improvement in quality, in speed, and in reduction of unit costs; and a wider use has been made of such records for the purpose of budgeting future activities, establishing schedules, laying down wise administrative policies, and otherwise aiding the centralized planning and control of all activities of the organization. The results in many industries have been revolutionary, and most modern corporate enterprises maintain research divisions and experimental laboratories as integral parts of their organizations. Many governmental bureaus, such as the Bureau of

Standards and the Bureau of Mines, carry on extensive industrial-research programs.

The application of industrial engineering methods to the various phases of the mining and metallurgical industry may be considered under three headings, corresponding to the three main steps in the solution of a problem by the engineering method of integration. These steps, as has been stated, are: fact-finding; analysis and presentation of facts; and planning and instituting new policies based on results of research. Brief discussions of various devices and techniques employed at each stage will be given, and their use in mine management shown.

FACT-FINDING: SOURCES OF INFORMATION

The first step in an engineering project is a fact-finding research, making use of original observations, measurements, and evaluations, or of records of such source studies.

Engineering surveys.—Throughout a mine's life engineering research and testing is being carried on for various purposes. Prospecting and development work is a fact-finding activity that seldom ceases. Surveys of sites for construction of mine plant, buildings, railways, and the like are undertaken to discover the best locations, to provide for efficient layout, and to discover the most economical routes of transport. The design of mine plants is a large subject which cannot be dealt with here, since such material is available elsewhere; but the layout of mine plant to provide for economic handling of operations is a not inconsiderable factor in mine efficiency.

Daily work reports.—An important source of management information is the day-to-day sheets turned in by foremen, shift bosses, timekeeper, storehouse clerk, mine superintendent, mill superintendent, and members of other departments. Developments in mine operation are too rapid to be adequately revealed by monthly or weekly reports; the alert manager demands information every twenty-four hours concerning the progress of the work. Entries in these sheets are made at first hand, and furnish an abundant body of facts which may be drawn upon in compiling periodic or special recapitulations and statements for particular administrative purposes. Forms of work reports may be found in Peele's *Handbook,* 2d ed., pages 1471–74; in *Mine Accounting,* by T. O. McGrath; in *American Mine Accounting,* by W. H. Charlton; and in other works listed in the bibliography.

Budgets and estimates.—Another source of information that is designed to assist in planning future operations is the estimates of needs—in money, labor, materials, equipment, and power—issuing from those in charge of various departments of the organization. The practice of budgeting future operations is one which might well be employed by mining companies to a greater extent. Looking ahead and anticipating coming needs will do much to cut down wasteful shortsightedness and loss of time while waiting for necessary materials. Preparedness should be the watchword all along the industrial front.

Performance studies.—Research in the performance of tasks by men and machines formed the basis of scientific management systems such as those worked out by Taylor and his followers, and efficiency studies of this sort may be beneficially applied to many stages of mining operations. Methods in use are scientifically observed and recorded, by means of stop-watches, job-analysis charts, and notes made on the spot; and the data thus obtained may be used for the purpose of erecting standards of performance (on which wage and bonus plans may be based) ; in preparing written standard-practice instructions for each task; and in making analyses aiming to reduce lost motion, fatigue, and unscientific procedures. At this point the need for the invention of better methods and tools often becomes apparent and leads to the discovery of new ways of performing tasks.

Taylor's warning against instituting performance studies without preparing the worker to co-operate should be repeated here. No one likes to have a stranger stroll up and, stop-watch in hand, scrutinize every movement made in the work. Nor is it possible to make reliable studies without the worker's knowledge; he should be frankly approached and convinced that the study will not react to his disadvantage. Motion-picture cameras have been used with great success in studying industrial operations; included in the picture is the dial of a clock on which the long hand moves every thousandth of a minute.

The technique of performance studies may be applied to determining the solution of such problems as effect of ventilation, lighting, and all other working conditions upon the efficiency and health of the worker. Studies in fatigue might reveal that hours should be shorter, or that a different arrangement of rest periods, holidays, or vacations would be more efficient in the long run.

Scientific research in mining and metallurgy.—Some sort of scientific research, formal or informal, is always going forward at most mines and metallurgical plants. Indeed, the work of the assay department might be called a routine research activity; and at one time or another the mine or mill superintendent will be sure to conceive the idea that operations at a certain point can be improved or that they must be improved if profitable extraction is to continue. The growing recognition of the value of organized scientific research in industry, both inside the laboratory and on the ground, is shown by the large appropriations of many companies for the support of trained research workers who apply their skill to the problems of heightening efficiency and reducing costs.

An extensive research program should be started as soon as the mine is in the dividend-paying stage. When the company is "flush" the moderate expense of maintaining a laboratory staff is seldom criticized; and investigations made in good times may discover life-saving devices that can be resorted to when the ore changes in grade or becomes more difficult to extract and beneficiate.

When a young engineer first takes his place in a mining organization he may be appalled by the magnitude and complexity of the operations that are being carried on, and is likely to feel that he can contribute no useful idea for the improvement of the methods that he sees at work. He should none the less have courage and bend himself to attaining a familiarity with all these processes that will in time give him an insight into the points at which improvement may be sought. He will at least be able to contribute a fresh point of view, and he may see openings that have been concealed from those whose curiosity has been somewhat dulled by routine.

The science of mining and treating ore is never complete; no matter how old or well established a system of operation may be, the alert engineer will continually be on the watch to detect new facts or sense new relations that may lead to a useful modification of procedure. The practical development of metallurgical science, which is based entirely on the laws of physics and chemistry, has in the past been largely the work of self-taught men with little or no scientific training. Many of these empirical discoveries have given excellent results; how much more, then, should the world expect of other men who come to the problem with a fine store of knowledge in the physical sciences. Such an experimenter in the field of applied science is in a position to know in advance some of the results that can reasonably be expected and also those which he cannot logically

hope to attain; he is skilled in scientific method and techniques, is trained in observation and mental honesty, and has some knowledge of the historical backgrounds of a problem; and his larger knowledge of the field permits him to see promising lines of investigation that would not be apparent to the untrained experimenter.

A research worker on the staff of a mine of moderate size in an out-of-the-way part of the world may feel that his chances of performing any useful work are negligible compared to those of a large and well-equipped laboratory staff of the sort maintained by large industrial corporations, trade associations, or universities. However, many of the greatest contributions to science have been made by solitary workers laboring under difficulties. Moreover, although his brothers in research elsewhere may have greater opportunities, he and only he is in a position to know the particular factors of the local situation; no distant expert can be expected to devise or adapt a method that would fit exactly the needs of the mine or plant that forms the scene of his endeavors. The most fertile fields of research in the future, it is believed, will be in certain branches of metallurgy. In general, the mining industry must treat ores of ever-decreasing tenor, and new methods of concentration and recovery will undoubtedly be discovered and applied. Other openings are in the discovery and application of little-known minerals and new alloys; the cheap extraction of plentiful and highly useful metals such as aluminum; the manufacture of steels having a higher degree of their theoretically attainable strengths; the application of research in pure physics and chemistry to metallurgical problems; studies of the properties of metals that have been subjected to extremely great centrifugal force; the heating of metals in a state in which carbon is not present—there is no limit to the possible fields of useful metallurgical research.

Study of professional literature.—Clarence King, a mining engineer of happy memory, used to tell a story of how he once set his heart on the ascent of a certain peak in the High Sierra because he thought it had never been climbed. With great exertion and at no little peril he scaled the precipitous mountainside and at last reached the summit, only to find at that hard-won point an empty tomato can and a copy of a recent newspaper—relics of a picnic party that had ascended by an easy trail on the other side of the mountain. A little preliminary research, he pointed out, would have averted this fiasco.

The first step in any research program is to inform oneself of

all available records of previous work bearing on the problem. "The difference between knowledge and research," says R. W. Raymond,

> is the difference between the expert and the discoverer. An expert is one who knows what has been done or is provisionally established in a given science or art. He can say, with regard to a new discovery or improvement, only whether or not it contradicts or transcends what is generally accepted as the result of previous experience. But the discoverer is a prophet, and, if he has not "spoken presumptuously," his message becomes a new revelation, and a part of the science of his day—or the day after.[1]

It is, obviously, a futile waste of time and talents for a worker to re-discover knowledge that has already been uncovered, stated, and accepted; that were to attain the mountain top in ignorance of the beaten path.

The research worker has two main sources of recorded information: (1) the past records of the mine, a careful examination of which may reveal pertinent facts which were noted in passing and which may later turn out to be of great importance; and (2) a careful sifting of professional literature.

There is a tendency for the engineer to think that his particular problem is original and that no one has ever before been able to reach any solution; but nine times out of ten a thorough examination of professional papers and the technical press will reveal valuable data on which the research program may be based.

The sources of technical information in non-ferrous mining and metallurgy, in the English language, may be listed briefly. First, there are textbooks and handbooks which cover the entire field to some extent; and most of these books contain useful bibliographies. Again, there are the transactions and bulletins of the American Institute of Mining and Metallurgical Engineers and of its British counterpart, the Institution of Mining and Metallurgy. Up-to-date references are obtainable from the indexes of current technical journals, such as the following American publications: *Engineering and Mining Journal, Mining and Metallurgy, Mining Congress Journal, Chemical and Metallurgical Engineering, Metal Industry,* and a number of more specialized publications and society bulletins. Files of magazines which have been discontinued — such as the *Mining and Scientific Press, Mines and Minerals, Mines and Methods,* and *Mining and Engineering World*—will yield some useful articles of less recent date. The most prominent British mining

[1] Raymond, R. W., "Knowledge and Research," *Min. Sci. Press,* May 1, 1915, p. 684.

publications at present are the *Mining Magazine* and the *Mining Journal;* the *Canadian Mining Journal* is another excellent source of information. Most of these periodicals contain notices and reviews of current books and articles. Again, a great number of bulletins and technical papers are issued by governmental departments, especially the Bureau of Mines and the Geological Survey, by state bureaus of mines and research stations, and by universities and mining schools. A monthly catalogue of public documents is issued by the Superintendent of Documents, Washington, D.C. The *Official Gazette* of the United States Patent Office gives specifications on processes and devices for which patent applications have been made.

There are also a number of periodical-index volumes which cover the field of mining in greater or less degree. Since 1912, with the discontinuance of Crane's *Index of Mining and Engineering Literature,* there has been no proper index which adequately makes available mining-literature references under subject-headings, and the research worker in mining and metallurgy is seen to be handicapped in comparison with the chemical engineer, who is able to turn to *Chemical Abstracts* for immediate and reliable synopses of all printed studies on a particular subject. The *Engineering Index* gives but little space to mining and metallurgy: the *Industrial Arts Index* is more helpful, especially in the management phases; and the *Public Affairs Information Service* is also of some value. Cannon's *Bibliography of Management Literature*, which was mentioned in chapter 22, devotes a section to mining.

The lack of a comprehensive index and abstracting service in mining and metallurgy has not gone unnoted in the technical press,[2] but at present each research worker is hampered by having to make his own index and keep it up to date. If some central body should take charge of this work there is every reason to think that volunteer abstractors, specialists in their subjects, would come forward and lend their services. Certainly it seems that a basic industry producing in the United States each year between five and six billion dollars' worth of useful minerals is entitled to have a proper index of its current literature.

Information is also obtainable from organizations such as the American Mining Congress at Washington, D.C., and through correspondence with university professors and other authorities, and

[2] See "Indexing Current Technical Literature," (edit.) *Min. Sci. Press,* Aug. 6, 1921, pp. 180–82.

with officials of mining companies who have undertaken research programs.

If an adequate preparation for a research undertaking, through a sifting of the technical literature, is not possible at the mine, the management should cheerfully send a competent person to the nearest large center where library facilities are available.

Some large companies have found it profitable to institute a central information service within its organization. To such a center might be sent a number of queries from the various departments which could be speedily investigated and answered by a person trained in this form of research.

ANALYSIS AND PRESENTATION OF FACTS

The second step in the research process is to analyze and segregate the facts discovered in original investigations and to present them in the form most suitable for the particular administrative purpose to which they are to be put.

Recapitulations and periodic statements.—The daily reports and work records are, as a matter of routine, recapitulated periodically in the form of production statements, payroll sheets, cost sheets, inventories, car-loadings, and the like. These records are of prime use in enabling the management to know how current operations compare with those in past periods and to plan for the control of future operations. They may also be compiled for special purposes, such as issuing annual reports, forecasting future trends, preparation of standard instructions, reduction of costs or accidents, guidance in development work, or otherwise promoting efficient management and recording important facts that may be needed in the future.

Charts, graphs, and maps.—In order to present quantitative and qualitative data in a form more speedily and easily comprehended, graphic methods may be used to summarize many records of observations.

A study of writings on the subject of graphic methods, such as those listed in the bibliography at the end of this chapter, will enable the research worker to select from the multifarious types of charts and graphs the particular form that will most accurately and compellingly convey the information he wishes to present. Since certain details are lost when a table of figures is epitomized graphically, it is important to know the pitfalls to be avoided in this work

and to follow the standard rules which have been formulated to guide chart-makers in attaining uniformity of technique.

It is not possible here to describe all types of graphs, charts, and maps which may be used by the management of a mine. However, a few examples will be noted to indicate how these devices may be used to present a condition and to inspire its correction, or to realize budgeted levels of attainment.

Labor turnover charts. A labor turnover beyond what is normally to be expected is a costly item which indicates that the management should uncover and correct its cause, which may be faulty employment methods, poor foremanship or supervision, unattractive wages, bad working conditions, or deficient planning and dispatching. A graphic study to isolate the causes of this situation should be undertaken, by plotting time-charts for each of the major departments, showing employment, absence, and replacement records of every man in these divisions. It should be supplemented by reports of interviews with men leaving or discharged. Such records may show that some foremen have difficulty in keeping their men, or that the company is at fault in not providing for the training of new employees. A study should also be made of the effect on production of slight reductions or increases in different working forces.

Gantt charts. A form of graphic record usually termed a Gantt chart is ruled to allow a space for each working day throughout several months. It may be used to indicate progress in production of the company as a whole, or of any department or division such as tramming, stoping, milling, etc. Some symbolic representation may be used to show whether or not the daily work has come up to the standard or budgeted amount. Such a chart will show at a glance whether or not the work is proceeding as rapidly as expected, and at what times the efficiency of the group is slack. In certain work where the daily task may be easily measured, such a record may be kept for every worker and special help may be given, or some more drastic action taken, to assist each man to attain the standard every day.[8]

Charts for information of employees. The posting of up-to-date charts of simple form in places where they can be noted daily by workers will keep up a lively interest in the progress of the work and encourage a beneficial spirit of competition. Each worker should be able to see at once what he or his group is accomplishing. For

[8] See Clark, Wallace, *The Gantt Chart.*

instance, in the roasting division of a copper smelter, where there are five or six large furnaces, each with a steady crew, a large chart might be posted showing for each crew the total tonnage handled, the assay value of ore before and after roasting, and the fuel and other supplies consumed. Such a practice might well lead to a reduction in costs and an increase in efficiency. If this is to be put into effect, it is a good idea to keep such records for several months without making them public, and then to compare them with the records several months after the men have been shown what they are accomplishing; this would give a measure of the value to the management of the policy of keeping the men informed on the progress of their work.

The increase of efficiency in this way may be accomplished in the simplest fashion, as is shown by an anecdote concerning Charles M. Schwab. A rolling-mill shift coming to work one morning saw a large "6" chalked on the floor. "Who did that?" they asked. "The big boss," was the answer. When their questioning brought out the fact that the figure represented the number of heats that had been put through the rolls by the previous shift, the men concluded that it was up to them to beat this record; and when their time was up, the chalked figure was "7" and the competitive spirit was fully awakened.

Some operations, such as development work or selective mining, do not readily lend themselves to competition in the matter of speed; and on such work accuracy or quality should be held up by the management as the suitable basis for competitive endeavor. Foremen should be on the lookout to see that competition does not lead to any sacrifice of safety precautions, or to tactics of obstruction, or to leaving repairs or clean-ups to be performed during the following shift.

Accident-prevention charts and bulletins. Analyses of accident records may be put to work in prevention propaganda by making and posting charts in various places where they can be seen by workers. One such chart may be extremely simple and useful; it is a generalized picture of a man showing on various parts of the body the percentage of mine injuries sustained in each part. This dramatic presentation will impress upon workers the warning to keep their heads, hands, shoulders, and legs beyond risk of accident. A small circular chart may show the percentages of accidents at various locations, thus drawing attention to the most dangerous spots in the mine or plant and encouraging the use of suitable precautions

at these places. Such a chart would probably show that the great majority of accidents occur underground; and a greater subdivision could then be made to indicate whether miners, timbermen, shovelers, powdermen, or some other group are most in need of caution and protection.

Construction schedules. A construction project may be systematically routed to completion at a scheduled date through the use of a graphic control chart on which are plotted the various parts of the work and the times at which each must be completed in order not to delay the schedule. The progress of the work on each job may thus be kept up to date, and if any job is slower than was expected special effort can be made to bring the work forward. It is a great mistake for an engineer to underestimate the time required for construction of plant and installation of equipment, although it is a mistake that has often occurred and caused expensive delay in starting operations. It is a much worse mistake, however, for an engineer to go ahead on a faulty program which does not take all items into account. For instance, if a mine smelter is completed save for the installation of a small power plant, operation of the entire works is held up.

Nomographs and control charts. In many standard operations the use of nomographs to facilitate calculations will be useful. Such a nomograph, for determining amortization factors, is shown in Figure 5, facing page 159. Other similar calculating charts may be devised for ore-selling schedules, prices of supplies, etc.

Control charts may be kept to aid in maintaining a certain quantity of supplies. A line on the chart would show what, in the manager's opinion, is the ideal level for the supplies inventory, and the curve representing accumulation and withdrawal of stores may be studied by the manager and the storekeeper to keep supplies close to the ideal inventory or to discover whether the ideal is too high or too low. Such a chart for various staple supplies might show periods of excessive buying or excessive use and permit correction of seasonal variation or enable purchase of particular materials during favorable seasons. Control charts of a similar sort may be employed in many of the other activities of the mine.

Among all the various types of ruled paper designed for making charts the logarithmic type is especially useful. The particular property of logarithmic ruling is that all relationships which involve multiplication, division, and powers or roots of numbers are represented on the chart as straight lines, which enables rapid comparison of curves and solution of problems.

Job-analysis forms.—Time and motion studies may be greatly facilitated by the preparation of job-analysis forms listing in order the various stages in the performance of a single task. It is then an easy matter for the observer to fill in the time and other observations—preferably in terms of some table of symbols familiar to him—and quickly obtain a record to be used as the basis for research in standards and efficiency. A decimal system for recording mine operations in code has been worked out by Dietrich.[4]

Mine accounting.—Another analytic process required for efficient management of a mine is the recording of operations in terms of dollars and cents. This process is termed accountancy, which has been defined as "the profession which has to do with recording, preserving, and verifying of facts concerning the acquisition, production, conservation, and transfer of values."[5] It differs from the mechanical process of mere bookkeeping in that it is a purposeful analysis of records of values and a clear and methodical presentation of the facts in the proper relations to show the true condition of the business. Mine accounting not only uses units of value to express relationships but combines the data derived from the use of records of quantity, time, and place.

It would be useless to attempt, within the scope of a few paragraphs or even chapters, to give any useful detailed facts on the subject of mine accounting—a subject about which volumes have been written and will continue to be written. Accounting practice in this field consists of a mass of detail which cannot be usefully generalized; there is no standard system applicable to the needs of all mining companies, and authorities differ on the procedure to be followed at many points. Nor is the young engineer expected to be a master accountant, which is a career in itself. If he comprehends the economic principles set forth in this book—the risks in the mining business, wasting assets and amortization of invested capital, depletion, depreciation, administrative and operating costs—if he understands that the primary profit in mining is the difference between the income from sale of mineral product and the expense of extracting, treating, and marketing this product; if he has supplemented his study of mining economics with a course in elementary accounting and is able to understand, though imperfectly, a profit-

[4] Dietrich, W. F., "Interpreting Time-Study Data of Mining Operations," *Engin. Min. Jour.*, Aug. 23, 1924, pp. 297–300.

[5] Greely, H. D., *The Theory of Accounts.*

and-loss statement and a balance sheet: then he may look forward without misgiving to the time when he will first come in contact with accounting as a practical part of a mine's operation—just as he looks forward with high courage to his first contact with the technical and scientific phases of the business after his entrance into the industry. Unless he is definitely pursuing the career of professional accountant in the mining industry or an allied field, this contact will probably come through the compilation or use of bookkeeping records as a part of his job in the field, or perhaps through a short period of service in the general offices of a mining company. At such times his interest in the practical problems of accounting will be greatest and will lead him to further investigations of the system in use and to wider reading on the subject. To assist his researches an extensive list of references on mine accounting has been given at the end of this chapter.

The account books of a mining company are of prime importance in assisting the management to exercise an intelligent control of operations, and frequent study of such records will point the way to improvements and changes required by efficient administration. A scrutiny of these figures, and comparison with available records of other organizations, will reveal many places where research in engineering methods and scientific management should be instituted in order to increase profits through acceleration of output or lowering of unit costs.

Cost-keeping.—Accounting records and statements are designed primarily to show the current financial status of the business, information which is of great value to the management, the directors, and the stockholders of a company, and is, as well, the basis of income tax reports required by law. A profit-and-loss statement, as its name indicates, is made out to show in detail the sum to be added to, or subtracted from, the net worth of the business as a result of operations during the fiscal period. The balance sheet shows the present financial obligations and resources of the company, in terms of cost or book values. Cost-keeping, however, is less a function of accounting than of engineering, and is undertaken for the purpose of aiding the engineer and executive to know in detail the amount of money currently spent at each stage in the extraction, treatment, and sale of the ore, and thus enable him to discover where economies may be effected. The value of cost records to the mining executive has been stated by an eminent engineer:

To the mining engineer with the necessary experience, who knows how work is done and should be done, cost-sheets thus employed afford suggestions and opportunities of making improvements he could not possibly make without them, which will often save a retrograding mine from ruin, or swell the profits of a prosperous undertaking. To the inexperienced engineer they are the best and quickest road by which to gain experience in a most important branch of his profession, and even to the non-professional, they are often of greatest value.[6]

Cost records are shown in terms of cost per ton, or other unit, of each division of the work. The list of operating costs in chapter 7 might serve as a useful arrangement for cost-keeping. In that place, operating costs are divided into development, stoping, transportation, treatment, administration at mine, maintenance, and city office expense; under each of these headings, the cost figure is segregated into labor, supplies, and power. The main headings might be further divided to give useful information; for instance, the various stages in treatment might each be itemized. Whatever the scheme used, the items should comprise *all* costs of mining. General charges, such as those for power, may be spread in some logical manner. It is not necessary to keep a set of double-entry books for a cost system; a simple series of loose-leaf recapitulation sheets, drawn from daily work reports, will ordinarily be sufficient, and the expense will not be so great as to defeat the purpose for which the system is intended. Weekly or even daily cost estimates should be kept; these serve as a barometer of the success or failure of current operations, and comprise the chief instrument of executive control. For example, as Ingersoll has pointed out, until the management has cost records it cannot even know whether or not the rock being hoisted and treated is ore, according to the definition of ore as an aggregation of minerals from which metals can be *profitably* extracted.

In many orebodies the metal content varies gradually and there is no sharp visual distinction between ore and waste. For a given mining cost a certain grade of material can be mined at a profit and will be considered ore. If the cost of mining this can be decreased a lower grade of material can be mined as ore. If the official in charge of a mining property is kept advised at frequent intervals of the costs in the various working places, the distinction between ore and waste can be accurately maintained. The property as a whole may be operating at a profit but if a certain orebody is being mined at a loss this should be known and corrected at once. The

[6] Charleton, A. G., "Mining Accounts and Cost Sheets," *Trans. Inst. Min. & Met.*, London, Vol. 5 (1896–97), pp. 250–51.

difference between success and failure of a mining property may depend upon a close watch of costs of the various operations.[7]

Cost charts enable the management to compare operations at any given time with those at any other time, to compare costs at the mine with those at other properties, to discover the effect of different engineering methods and management policies, and to attempt to forecast intelligently the probable trend of future production.

Reports to stockholders.—Aside from periodic reports made by the mine superintendent, geologist, and other staff officers, and by the mine manager to the board of directors, there are also a number of fact presentations made by the mine management and administration to the shareholders. These usually take the form of a quarterly or an annual report, the purpose of which should be to keep the shareholder—the real owner of the property—fully informed upon the current status of his investment. Too often, however, such reports are issued as a mere formality, and contain much information that is of no use to the stockholder or anyone else; or, worse yet, the statements made are sometimes deliberately drawn so as to be not easily understood by the reader. Some standard form of report, giving useful information clearly and concisely, has been advocated for some years with little success. Voluntary reform in this matter cannot be expected of most companies, and until standardization of the terms and procedures in reports to shareholders is made compulsory, the public cannot hope to obtain all the useful information from this source to which it is entitled. (See chapter 17, pp. 330 and 333.)

The annual report to shareholders differs little in substance from a report on valuation as discussed in chapter 11. The same subjects should be covered, and the primary purpose should be to enable the investor to determine whether his capital outlay will bring in, or continue to bring in, a fair return. The purpose of an annual report has been clearly defined by McGrath:

> A yearly report of a board of directors to the stockholders of a company should be an account of the management by the directors of the stockholders' property. The purpose of such a report is to show:
>
> 1. The condition of the business of the company at the close of the year.
> 2. The results of operations for the year in profit and loss, and in dividends paid or assessments levied.

[7] Ingersoll, Guy E., "A Method of Compiling Approximate Mining Cost Data," *Engineering Bulletin* No. 37, State College of Washington.

3. The setting forth of necessary details and fundamentals of operations in such manner as to permit any intelligent stockholder to acquaint himself with the expense and cost, production and earnings, etc., of his property; to enable him to make an intelligent comparison of the year's results with those of other properties of like nature and to allow him to judge correctly the future possibilities of his investment.[8]

Recommended forms for annual reports—covering the statement of the manager concerning the details of operations for the year; the treasurer's report on costs, earnings, and income for the period; and, finally, the balance sheet showing the condition of the business at the end of the period—are given in McGrath's article and in various other references in the bibliography.

Unfavorable developments, as has been said previously, should be reported to the shareholders with as much frankness as are more fortunate discoveries.

Many directors seem to think that bad news can be improved by suppression. They hope that something will turn up that will make the position better, but engineers should fight hard against this practice of keeping shareholders in the dark. The proprietors have as much right to know the trend of developments as the persons they delegate to look after their interests. If the news is likely to depress the price of the shares that is the more reason why it should be published, because a buyer on faith that the situation is as publicly believed, whereas in fact it is not so, has been defrauded, and anyone who silently acquiesces in concealing the truth from him is a party to the fraud. These statements apply as much to mines in operation as to properties in the earlier stages of development.[9]

Classification and filing.—In the absence of a comprehensive indexing service for mining and metallurgical literature it is necessary for each company and each engineer to keep a file of references and clippings which may be needed for research purposes. Such files have a way of getting out of hand and may easily demand more time and space than can be justified. The young engineer starting to practice should recognize that it is not necessary for him to make a complete file of all printed matter concerning every phase of his profession. Lack of shelf space and frequent removals will make an unwieldy file a great burden. He should confine his collection to important contributions on a few special subjects that directly concern his work and interests. The filing habit may be dangerous: it is much

[8] McGrath, T. O., "The Standardization of Directors' Reports for Mining Companies," *Engin. Min. Jour.*, May 4, 1918, p. 825.

[9] Marriott, H. F., *Money and Mines*, p. 103. Quoted by permission of the Macmillan Company, publishers.

better to read an article and discard it than automatically to file it unread in the expectation that some day it will be needed.

Such selected material as the engineer or the company may logically expect to use should be systematically filed and indexed by some method that will make a particular item readily available. In many cases a simple subject-index on library cards, each containing a reference and a brief abstract of the material, will be sufficient to direct the worker to files of magazines, pamphlets, and technical publications; loose-leaf notebooks may also be used for this purpose. The Dewey decimal system, familiar to library workers for classifying works on various subjects, has been extended to cover mining and engineering.[10] Indexed scrap-books for small clippings should be kept to contain short items of special interest.

Most organizations use some numerical, mnemonic, or code system of classification for operations, products, raw materials, equipment, personnel, and the like. These are necessarily devised to fit the needs of the particular situation, and the use of such "shorthand" methods of designation is an important part of efficiency in management. One such method in mining is the classification of working ground according to the needs of each class.[11] Another, especially adapted for messages by wire and cable, is McNeill's Code, which gives word and number equivalents for thousands of expressions used in mining. Secrecy may be obtained in the use of this code by agreeing beforehand on a key number. For example, in the 1908 edition the word "schiavitu" and the number "96116" both convey the information that "the vein shows signs of a pinch." If the key number is "13 forward" the word "schiafnase," number 96129, would appear in the message instead of the code word actually revealing the meaning; the recipient would obtain the true message by counting backward thirteen lines. Special words for names of persons, processes, and local places may be added to the code by prearrangement.

Mine maps, charts, and tracings suffer exceedingly from wear and dirt, and should be filed with especial care. Reinforcement of edges and punched holes is usually necessary to prevent tearing. Maps should never be folded or rolled, and should be filed preferably in large horizontal cabinets.

[10] See Durham, E. B., "Filing Technical Literature," *Engin. Min. Jour.*, April 29, 1916, pp. 784–86.

[11] See Harley, Townsend, "Proposed Ground Classification for Mining Purposes," *Engin. Min. Jour.*, Sept. 4, 1926, pp. 368–72; Sept. 11, pp. 413–16.

PLANNING: USE OF ADMINISTRATIVE RECORDS

The final step in efficiency studies is the application of records and research results to the organization, through wise administrative and supervision policies intended to reduce labor and costs, increase output, and otherwise produce profit in the form of dividends and better industrial conditions. The synthesis and utilization of facts concerning the work enables the planning of future operations and the substitution of more exact and scientific procedures in place of the wasteful, hit-and-miss, shortsighted policies too often prevailing in the mining industry in the past.

The applications of most of the research functions previously discussed are already apparent. Estimates of future needs permit the administration to budget future activities logically. Reports, financial statements, and charts serve as a basis for inaugurating new methods, obtaining co-operation of workers, and, through furnishing directors and stockholders with accurate and clear information, improving the relations of the various parts of the organization, as well as its relations with the public. Financial records also supply necessary data for required statements, reports, and tax returns. Research data are also useful for administrative forecasting; for example, cost records will show the selling price for metals at which the mine cannot operate at a profit and must shut down. In general, however, the mining business involves so many contingent factors of extreme uncertainty that painstaking statistical analyses are of little use as compared to the value of such studies in more stable industries; and probability techniques, except for such purposes as sampling the quality of supplies or the like, will not be called for.

The utilization of research results in certain fields, however, demands a few words of comment. These fields are summarized in the last seven of Emerson's efficiency principles.

Standard methods and instructions.—Scientific determination of "the one best way" to perform a given operation, both in the use of tools and materials and in the procedure of the worker performing the task, permits the standardization of this method and should be embodied in written instructions for standard practice throughout the mine and plant. At the time these instructions are drawn up, the co-operation of several intelligent and expert workmen should be obtained; the suggestions and criticisms of these practical men will almost always improve the value of such documents. The advantages

accruing through the use of standard instructions have already been mentioned in chapter 22.

Dispatching schedules.—The central planning of standard operations will enable the drafting of schedules for routing the work throughout, for the purpose of cutting down unnecessary transportation expense and keeping the equipment and force operating at maximum capacity. This planning will be facilitated by graphic charts showing the "load factor" at each stage in the operations. It may be useful to have in each part of the plant a worker charged with acting as a routing clerk—a "secretary to the machine," as he has been termed—who lays out the various jobs to secure maximum use of equipment, giving the right-of-way to more important tasks. This practice is especially useful in shops or in controlling the work of maintenance crews—activities which are not directly dependent upon the flow of ore from the mine.

Invention.—Analysis of records will frequently bring to light facts which have hitherto been obscured or underestimated, and will reveal a need for the correction or improvement of a faulty condition. As soon as such a need becomes apparent the inventive instinct is spurred and the mind sets to work to discover the solution to the problem. Attempts to attain such a solution will involve a new program of research, which may in turn show that the problem is at present insoluble or, on the other hand, may result in discoveries that will have impressive and far-reaching effect on the attainment of profits.

Imagination.—It may be well at this point to insist once more upon the obligation of the engineer to assume at times the rôle of prophet. Imagination, controlled and directed to the conception of useful engineering projects, is the prime qualification for a successful engineer in any field; the engineering mind, despite the stupid popular impression, cannot be prosaic and unimaginative, for at the inception of any project the engineer must be able to picture each successive step of design, construction, and operation, to foresee and counteract all threatening factors, and to envisage the social and economic consequences of his plan. Every engineering enterprise was at one time the dream of some imaginative engineer. There is no need to dwell on the fact that because of lack of sufficient data or faulty research methods some engineers in the past have made poor prophecies; the obligation remains. The mantle of inspired Elijah, however, lies uncomfortably on modern shoulders; it has given way to the blueprint, the laboratory, the field survey, and all

the other research instruments through which the engineer may envisage the new day, and plan for its coming.

The practice of maintaining accurate records and instituting special researches is the chief means by which the management may promote efficiency in industry, cure many of the tremendous wastes in production and operation, and set forth an intelligent administrative policy for the guidance of supervisory officers. Results of these studies will provide a sound basis for imaginative planning, for the application of the principles of the fair deal, and for the erection of a consistent reward to workers for efficient performance of their labors.

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Chapter 24

Industrial Relations in Mining

The industrial relations of a mining and metallurgical company may be discussed under the following headings: motives that actuate workers; relations of capital, labor, and management; wages, and methods of determining a proper wage; efficiency of laborers of various nationalities; and functions of a personnel department. Chapter 25 will deal with the educational activities of a mining company, the maintenance of discipline and the fair deal by foremen and other supervisors, and certain disciplinary problems.

WHY MEN WORK

Most writers when dealing with the subject of rewards for labor performed apparently assume that there is a single reason why men work—to obtain a cash wage—and confine their discussions of labor problems to the sole topic of wages. It would appear, however, that there are a number of other motives for working, aside from a pay check, which actuate men in greater or less degree. If this is true it then becomes a part of the duty of management to understand these motives and to provide for their satisfaction, if efficiency of personnel is to be increased.

The acquisitive instinct.—The "economic man" of the Manchester school was conceived to be a creature whose mainspring was a selfish greed for monetary profit, and on this premise the "laws" of economy, flowing from this prime mover, were held to be natural and immutable, and hence not to be tampered with (*laissez faire*). Under an economy of scarcity such as that of the nineteenth century the defects of this theory did not clearly reveal themselves; but the weight of a world-wide depression had caused many people to question existing theories and to speculate upon the possibility of deliberately working out an economic system that would be the instrument of society rather than a harsh, masterful, and wayward machine to which man must be subservient. Under such a new order

due allowance should be made for the accumulation of other forms of profit than the heaping of dollar upon dollar.

The ultimate aim of an economic system is the same as that of civilization and of the engineering profession—the attainment of a maximum of average individual comfort. This cannot be achieved until we rid ourselves of the idea that acquisition of money is now —if it ever was—a good index of service performed for the benefit of society. In fact the purely acquisitive instinct is frequently in direct opposition to the needs of a good economic system; it almost always leads, not only to dissipation and vulgar display, but to sterilization of capital, anti-social exploitation of human beings, corruption, overproduction, and waste through speculation and unwise allotment of resources. When it does this it is surely the right of society to protect itself against such misuse of a common heritage.

Other motives of labor.—Fortunately, most of us perform our daily duties for other reasons than the simple one of attaining great monetary wealth, or the economic system would be racked even more than it now is by millions of persons striving, by honorable or dishonorable means, to pile up a golden fortune. The most obvious of these additional motives for working may be listed:

1. *Economic security.* One of the greatest fears that haunt all workers today is that loss of the opportunity to work will bring want and suffering to the worker and his family. It is to be questioned, however, whether this motive is a noble or worthy incentive to work, and it might further be suspected whether its power to keep workers on the job is not greatly offset by reductions in efficiency caused by worry, and by danger to the economic system caused by a fear-driven desire to attain money by any means in order to protect the worker and his family from poverty. It may be seriously doubted, since fear of economic insecurity is not the sole motive for work, whether some form of wise unemployment insurance would totally remove all incentive to work; in fact, in most cases the unemployed man desires no more than a chance to earn his living, and is reduced to needy circumstances through no fault of his own. To guarantee a minimum living to all citizens would be a worthy and not impossible aim for the people of the United States. In one sense our humanitarian feelings do now assure to everyone at least enough food to stave off starvation; but it is given in the form of grudging and degrading "charity" rather than through a chance for the worker to earn a living wage.

2. *Service.* The ideal of performing work as a common service to society, although it has been prominent at various periods in the world's history, has emerged with such strength in the past few decades that it may well become the ruling ideal of the twentieth century. The increase in self-respect, and the feeling that one is performing his share in the work of a group with a worthy aim, appeals more and more to many men as a satisfying motive for devoting their efforts and talents to a useful task. This motive has always been explicitly recognized in the stated ethical practices of any class pretending to be a profession—in fact, the performance of a service beyond the letter of a contract, and for what is conceived to be the public good, is the distinguishing difference between a profession and a trade. Not only clergymen, but doctors, lawyers, scientists, government officials, teachers, newspaper editors, engineers, and other professional men have time and again acted against their personal monetary interests in order to fulfill what they conceived to be a higher duty. It may be noted here that there are two kinds of service: voluntary service as outlined above, and compulsory service, as demanded by the collectivist state.

3. *Pride of the artisan.* A third motive, which has actuated men since the savage first chipped a flint arrowhead, is the satisfaction derived from creative endeavor and the efficient practice of a craft. Too often charges against the increasing use of tools and machines as a narrowing and deadening influence in modern life have been made without remarking that there is often a compensating satisfaction in the operation of mechanical devices; that, in fact, machines may give increased pleasure through giving broader scope for expressing the creative desires of the artisan and through extending and realizing human powers to the fullest extent. The operation of an automobile, for example, is seldom irksome, but rather gives a human being a pleasant sense of power and a chance to exercise the manipulative instinct to modify and improve his environment. A mine worker may run a power drill not merely because he is paid money to run it but because he likes to run a power drill and is happiest when doing it. The creative urge of the artist, attempting to make the most satisfying use of his materials of expression, is a psychological drive often completely divorced from monetary considerations, and is indeed often hampered or perverted by the need for earning a living.

4. *Social recognition.* The ambition to attain fame, honor, or social prestige is frequently a strong motive for work. Not only may

the soldier volunteer to face certain death in the hope of glory; but thousands of other men in less spectacular walks of life may also render conspicuous service in the laudable desire to win repute and social approbation. This hope changes a "job" into a "career."

5. *Exercise of power.* Any increment of wealth beyond the amount of food, clothing, shelter, or other commodities which can be used or consumed by an individual is in reality an increase in power to direct the human activities of the globe. This desire for the pleasure that comes in organizing and controlling affairs often keeps men at their desks for years after they have attained sufficient wealth to keep themselves and their families in luxury for a lifetime.

6. *Instinct to work.* Last, and far from least, is the human desire to *do* things, to be active in the performance of self-imposed tasks. Mankind may look upon irksome labor as a necessary evil, the "curse of Adam," but leisure classes have always been small and self-destroying, and a deep-seated urge to conquer its environment has implanted in the race a trait having great survival value. Play in children is almost always of a sort comparable to the tasks of the workaday world, and the most satisfying play of adults is a hobby or some other useful or productive activity which, if imposed by necessity, would be termed work. Nothing is more tedious than an enforced and inactive vacation. Much dislike for work, as such, is directly traceable to a dislike for work for which a person is physically, mentally, or temperamentally unfitted; while, on the other hand, if a man is not a round peg in a square hole but can feel that he is well suited to perform his duties effectively, his work becomes distinctly pleasurable. Wise personnel selection can work wonders.

These various motives for work, then, should be kept in mind along with the wage motive when considering personnel supervision and administration of industrial relations—a management activity which, if undertaken in a scientific spirit, will return a profit to the company in the form of properly selected workers, freedom from strife, adequate work for the wages paid, lowered labor turnover, and increased efficiency resulting from the improvement of the general welfare of employees.

RELATIONS OF CAPITAL, LABOR, AND MANAGEMENT

Distribution of profits.—The classic school of economy was accustomed to speak of three factors of production—land, labor, and capital—and to allot, to each of these, one of three classes of income

—rent, wages, and profits. There is a fourth factor, however, which since the inception of the Industrial Revolution has developed the right to claim a share in income from production, the factor of management. At the beginning of the nineteenth century it was still possible for a capitalist to perform the functions of management; but as the body of technical knowledge grew and expanded, it became less easy for a business man to obtain the training and experience requisite for the management of a large industrial plant. The growth of the corporate form of organization further tended to divorce the function of the capitalist from that of the manager, who became a sort of high-class laborer lending his technical skill to attaining the desires of capital. The ideal of the engineer-manager —the efficient production of goods—was often at odds with the desire of investors—the accumulation of profits; while the aim of the laborer—to attain higher wages for a given amount of work— was almost always contrary to both.

> As a matter of fact, ownership of this and of that began to lose its importance with the rise of the investor class, when one person had the factory and another a piece of paper covering the factory. The crux of the matter is, who receives the factory income? As the case now stands, it is a six-cornered fight between the landlord demanding rent for the land on which the factory stands, the bondholder demanding interest on his bonds, the stockholder demanding dividends, the worker demanding wages, the management demanding salaries and bonuses, and the state demanding taxes. If the worker or the state wins out, it is socialism; if the landlord, bondholder, and stockholder win out, it is capitalism; if the management wins out it is, so far, unnamed.[1]

The engineer-manager has been content to serve as a sort of buffer between the factions of capital and labor, but only he is in a position to exercise adequate control over the workings of the production system in a technological society. It remains to be seen whether the engineer, who has formerly been left out of consideration in industrial conflicts, will be able to assert his claim to a share in the profits of production commensurate with his service and to attain in greater degree his ideal of an increased modicum of average individual comfort for the whole population.

The weapons wielded by capital and labor in their struggle for a greater share in the profits of production have been listed by Veblen under the appellation of "sabotage," which he defines as "conscientious withdrawal of efficiency." He says further:

[1] Chase, Stuart, *A New Deal*, p. 39. Quoted by permission of the Macmillan Company, publishers.

> The word has quite unavoidably taken on a general meaning in common speech, and has been extended to cover all such peaceable or surreptitious manoeuvres of delay, obstruction, friction, and defeat, whether employed by the workmen to enforce their claim, or by the employers to defeat their employees, or by competitive business concerns to get the better of their business rivals or to secure their own advantage.[2]

Strikes, lockouts, injunctions, "soldiering" on the job, and restriction of production by administrators or by the government fall equally under this head. Such resort to wasteful, even if legal, force will never solve the problem equitably. Indeed, the exercise of sabotage by labor has frequently resulted in the increase of so-called technological unemployment through spurring the invention of automatic methods and machines to supplant the human worker and prevent the possibility of conscientious objection.

In order to prevent wasteful and dangerous recourse to force and deliberate inefficiency, attempts have been made to resolve industrial disputes through submission to a board of arbitration. Advocates of this method hope that airing of the problem before a legally constituted court will lead to the application of the fair deal and acceptance of the court decision to the mutual benefit of both capital and labor. However, as was pointed out in the previous chapter, it is impossible to apply the principle of the fair deal until scientific research has revealed what course of action will, in actuality, result in benefits to both sides. The difficulty in trying to settle disputes through arbitration is that judicial compromises satisfy no one, and such verdicts—since the theory of arbitration rejects the appeal to force—are easily disregarded or contravened. The Commonwealth of Australia has given the principle of arbitration an earnest trial for a period of thirty years. All the necessary machinery has been carefully constructed and revised from year to year; both sides have attempted with great sincerity to co-operate; but arbitration in Australia cannot be said to have realized the hopes that its friends have held out for it. The reason for this seems to lie in the fact that any agreement may be nullified by a minority of individuals on either side who are disinclined to carry out the awards of the arbitration courts instituted and elected by their own group; and if the majority attempts to effect its will by force, then conflict, instead of being eliminated, makes its way even into the ranks of the party itself; for arbitration fails the instant force is introduced.

It would seem that the only hope of reconciling the aspirations

[2] Veblen, Thorstein, *The Engineers and the Price System*, pp. 1–26.

of capital and labor is the application of the engineering method of integration to problems of industrial relations. The wasteful results of sabotage can be avoided in no other way. A complete array of all the facts which enter into any given capital-labor adjustment, and a candid evaluation of them by both parties in the presence of a moderator representing the third party to the situation, the public, often leads to a revaluation of many factors and the abandonment of many more which are obviously invalid. Research brings out the facts, upon which the principle of the fair deal may logically be based. An intelligent examination of the conditions in this new light will frequently make possible the synthesis of a feasible working plan, consistent with the true requirements of the situation. Application of the engineering method, then, takes the industrial problem out of the realm of conflict (sabotage) and judicature (arbitration), and permits progress in accord with correctly adduced scientific principles. A plan of procedure reached by integration is more likely to have public sanction than one arrived at by sabotage or arbitration.

Labor unions.—Theoretically, every man has a right to work for whatever wage he may choose to accept. The coming of the Industrial Revolution, however, left fewer jobs to be filled, while permitting an increase of population through greater production of the necessities of life; and hence, with a surplus of labor available, it was possible for shortsighted employers to encourage competition among laborers and beat down the worker to the lowest possible wage. To counteract this power, labor unions were formed, organizations through which the worker might bargain with capital for improved conditions; and their efforts have undoubtedly been of great value to all working people in correcting many industrial evils and securing improved working conditions, shorter hours, and recognition of the social importance of labor.

On the subject of the right to strike, Herbert Hoover, as engineer, statesman, and humanitarian, speaks with moderation and the utmost clarity.

> Because everybody has more cash in his pocket and in the bank, there is an illusion which always comes with the ending of war and its inevitable inflation. That illusion is that we have grown richer and more prosperous. The contrary is the case. The fact is, the American people have been terribly impoverished. That impoverishment will develop later and recovery from it depends upon two things.
>
> First, on whether our people are willing, at least for a few years, to work more efficiently than ever before and thus restore their lost wealth.

Second, recovery depends on what progress we can make in the application of labor-saving devices, new methods, new inventions and scientific discoveries, which increase the productivity of each individual and of the nation. These being the facts, some blunt words are needed.

At the desk, the bench, and on the farm, men and women must give the best that is in them during reasonable and healthy work hours without artificial limitations on effort.

The initiative of men must be restored and encouraged so that labor-saving devices, scientific discovery, invention and new enterprise may have full development.

Exceeding the limits

Widespread strikes which paralyze production defeat this course. We cannot make economic or social recovery if we are to have a repetition of the unparalleled industrial conflict of 1946.

Nobody denies that there is a "right" to strike. But there are extremes at which any "right" becomes an oppression. There are legal limits even to the right of free speech. When the "right to strike" was fully accepted, strikes were believed to be solely pressures on employers to improve working conditions and wages. But a new idea has now grown up around the use of the strike: that this weapon can be employed for political and ideological purposes and that it can be used so to injure and endanger the people at large that in their misery they or the government will be forced to do the strikers' bidding. It is the people who suffer.

By the use of this tactic there have arisen in the United States a dozen men who now wield power over the life and living of the people greater than the government. They have never been elceted by the people. Years of battle by the people finally eliminated such oppressions by arrogant business leaders.

Powers needed

The time is now here when strikes which endanger the life and living of hosts of people not party to the dispute must have prompt settlement. We must have more effective methods of collective bargaining and mediation before a strike is resorted to. In addition, the judicial machinery of the country should be given power and penalties to end any strike which the President, through the Attorney General, declares constitutes a danger to large numbers of innocent people.

But in order that justice be done, there must be further provision for arbitration conducted by delegates from both sides, together with independent members. The decisions of this group, arrived at by majority vote, should be final. I have always opposed compulsory arbitration as a limitation on the right to strike, but that right has now been carried to extremes. It is necessary to check this destruction if the people are to be masters in their own houses.

There is a heavy responsibility on all of us as we move into the new year. We must master the difficult art of working together. No country can move forward when its machinery stands idle. Only through production can we recover from the war, and keep America strong, prosperous and free.[3]

[3] *New York Herald Tribune,* December 29, 1946.

Since labor unions are admittedly fighting groups, primarily designed to win as many special privileges as possible for their group, their attitude in general has always been one of opposition rather than co-operation. Although some unions have been definitely helpful and constructive, union activities in the past have many times been harmful to the social-economic structure. In the first place, they have never pretended to wish to take over any of the responsibilities of management; their highest aim is to win the "full dinner-pail" and attain special rights and rewards not available to their unorganized fellows. Although union enthusiasts have asserted time and again that complete unionization would immediately solve the problem of industrial co-operation, experience in England, in Australia, and in some of the highly unionized industries in the United States has revealed that no such millennium comes to pass. In many places union influence has failed to improve public welfare and has, on the contrary, been obstructive and unmindful of the rights of the general population. Frequently the acquisition of great power has worked against the true interests of the worker by discouraging business enterprise, as has been the case in union-ridden Australia. Again, insistence upon the principle of the "closed shop," which has also engendered great ill-feeling, has been based on the absurd notion that 15 per cent of all the workers in the United States have the right to exclude from work the remaining 85 per cent. Resort to strikes and other forms of sabotage and force is nearly always directly against the public good. An especially dangerous practice is the importation by a local union of professional agitators whose living is won through industrial strife and who ordinarily have no good understanding of the various factors involved in the local situation.

There is a trend in the recent history of the labor unions toward collectivism; at the same time there is no group in our body politic who has a greater stake in the maintenance of democracy and a suitably controlled free enterprise. The greatest step they could take toward the accomplishment of their laudable desire for adequate wages, security, and safe working conditions would be the election for their leaders of men of brains, determination, and good manners. Labor does not lack men of this sort.

Finally, the principle of equal day's pay for all employees regardless of the quality and amount of work performed by each individual —a principle advocated with grim tenacity by union leaders—is stifling to human initiative and contrary to every principle of scientific

management for efficiency, as will be shown in the next section of this chapter.

Management and the union.—It is sometimes possible for a management to offer the union other vents for their energies than the sole and selfish aim of attaining extravagant wages. A number of useful activities can be placed upon the shoulders of a miners' union in any district. Its officers and members are commonly quite keen to assume responsibility for the social betterment of the community and for the provision and supervision of amusements, athletic contests, and the like; in some cases union members may take a leading part in vocational-training work.

If the mine management must deal with unions it may legitimately encourage workers of intelligence and moderate principles to join the union and take an active part in its discussions and activities. Such men may leaven the lump and act as an antidote to the professional agitator, since they are frequently able to appreciate the point of view of the management and may serve to maintain harmony by representing labor in its relations with its employer. There should, of course, be no attempt on the part of the management to give such men any special privileges which may have the appearance of a subsidy; talebearers should be discouraged, and anything in the nature of systematic espionage on the union councils should be rigidly avoided.

In spite of the efforts of management to appease and conciliate the workers in difficult times, it is sometimes impossible to avoid the outbreak of an organized strike. Labor troubles have existed in the United States from Colonial days; the first strike recorded was in New York City in 1741, and a strike in the coal mines on the Monongahela River in Pennsylvania occurred in 1848. There was a succession of outbreaks on the Mother Lode in California in the early 'sixties, resulting from the replacement of black powder by dynamite, the introduction of Chinese labor, and, later, the replacement of hand drills by machine drills. In the early strikes there was ordinarily no complaint by the men regarding the manner in which they were housed or fed or personally treated, for their bosses were usually men of their own type who had risen from the ranks of the industry and who worked side by side with their employees. It has been unfortunate that the displacement of the old-fashioned boss by the technical man representing a large company organization has often led to needless disputes, resulting from suspicion on the part of the workers and lack of understanding of the workers' atti-

tude on the part of the technical man. Such chances for friction have been much mitigated in latter years through the choice of mine managers with real qualities of leadership, and through the efforts of capable personnel departments to foster better understanding and closer co-operation between laborers and those directing the work.

Although the number of industrial clashes is lessening it is not likely that the possibility of strikes will ever be completely removed. Occasions arise in the conduct of nearly every mine of any size when a strike seems inevitable. If the manager has made a careful study of the conditions and has accurately interpreted the portents of storm, he may become convinced that the elements of the situation are irreconcilable and take steps a long time ahead to avert a dangerous crisis. The first step would be to go before the board of directors and present his opinion that there is no middle road and that the mine should be unobtrusively shut down. The farther off the storm can be predicted, the more useful this method becomes. Operations can be curtailed gradually by reducing tonnage week by week and laying off a few men at a time. Needed alterations in the plant, extension of development work, or a number of other unusual tasks may be undertaken to occupy the interim, until lapse of time and shifting of the threatening factors in the situation permit the resumption of operations. Although this procedure has never received much publicity it is successfully used in many cases to prevent destructive outbreaks that harm worker, mine operator, and public alike. It differs entirely from the "lockout," or shutdown on the eve of a strike, which is a violent measure of reprisal that can only aggravate the situation, and which is "sabotage" as defined by Veblen.

Labor situation today.—If this republic is to endure, some way must be found successfully to operate the complicated relationships of labor, capital, and the public—with special emphasis on the public. Hitherto the public has suffered most in the various contests. A wise test in any controversy between capital and labor is to measure its result on public welfare.

WAGE PLANS IN THE MINING INDUSTRY

It is difficult to see why many other phases of the mining business are discussed in all their details while the cost of labor—which in most cases amounts to more than half the cost of mining and is often the deciding factor in a project—should be frequently neg-

lected. The largest savings that may accrue from applications of scientific management may be won in this large item of labor cost.

There are several methods of paying for work in the mining industry. The most prevalent of these are the *day's-wage, piecework* or *contract,* and *bonus* methods. According to a study of information circulars issued by the Bureau of Mines,[4] a number of metal mines in the United States use these methods in the following percentages: 40 per cent do practically all work on a contract or bonus system; 18 per cent do development work on contract and other work partly on contract or bonus system and partly on day's-wage basis; 18 per cent do development work on contract and all other work on day's-wage basis; 16 per cent of the mines are on a day's-wage basis; and 8 per cent are on day's-wage basis except mucking, which is done on a piecework basis. It is thus seen that although some form of special incentive plan—such as a contract or bonus method—is favored for most of the work, especially development, the day's-wage system still prevails in many places.

Day's-pay basis.—Much of the opposition of union labor to the advance of scientific methods of management was aroused by revelations of inefficiency in the day's-pay wage plan, which has always been one of the fundamental tenets of unionism. The insistence upon an equal wage for all classes of workers, regardless of the amount or quality turned out by each individual, puts a premium upon slacking, drags efficiency down to the level of the least able worker, discourages individual initiative, requires an undue expense for supervision, and puts upon the supervisory staff the necessity of incessantly and degradingly driving the men to perform the labor for which they are being paid. The method has attained practical results only through the efforts of foremen, shift bosses, and managers to discharge lazy and inefficient workers as fast as they are detected; so that there is much waste involved in ultimately building up a group of workers who have the qualities of skill and initiative. It is possible to use this method, however, in open-cut mines and others where large and uniform deposits permit the determination of a standard task to be performed by the average worker within a certain time. Moreover,

for many branches of mine labor, as engineers, mechanics, foremen, office force, and miscellaneous laborers, the day's-pay system is the only prac-

[4] See Wright, Charles W., "Management of Labor in Successful Metal-Mine Operations," *U.S. Bur. Mines Infor. Circ. 6650,* Aug. 1932, p. 6.

ticable one. For underground work, day's wages are also preferable to contract arrangements in those mines in which the minerals are irregularly distributed, requiring discrimination in the separate handling of ore and waste, or in which the mining conditions are difficult, demanding slow and painstaking operation; both of these objects are likely to be defeated by any system which aims to promote speed.[5]

Contract or piece-rate systems.—The ordinary piece-rate system used in the manufacturing industries, whereby performance of labor of a standard sort is paid for at a standard rate, is seldom applicable to the multifarious tasks of mining. It is always difficult to determine how the amount of work performed is to be measured and what should be the rate of pay at different times. The piece-rate idea, however, is used in mining through the assignment of contracts for the performance of a certain task at a stipulated sum—tasks such as the stoping of so many tons of ore per day, the driving of so many feet of opening, or the drilling of so many feet of holes. Under nearly all of these systems, as employed in the mines of the United States, the worker is guaranteed his daily wage should he fail to attain a higher return under the contract. In other words, he will share in the profits but not in the losses. In this feature, whereby the worker is protected against the risk of mining, these wage plans differ from true leasing systems, which are described in chapter 12.

The contract system usually results in more efficient performance than does the day's-pay system, since it puts initiative upon the worker and thus spurs him to work harder than he would for an employer. From the point of view of the mine operator, the contract system promotes speed, reduces unit costs, and diminishes the charges for supervision; moreover, he can determine with more certainty ahead of time the cost to him of a given undertaking. Meanwhile, the contractor is able to obtain special reward for his energy and ability. The system has been applied to almost every part of mine operation but is especially successful in development work and in any other type in which the quantity and quality of the work may be readily estimated, measured, and inspected.

The contract system, however, suffers from a number of drawbacks when applied to most mining operations, which are necessarily irregular and unpredictable. Disadvantage of the method are many:[6] difficulty of operator to enforce standards of workmanship and safety; disagreement concerning price to be paid and other terms of

[5] Peele, Robert, *Mining Engineers' Handbook*, 2d ed., p 1527.

[6] See Peele, *op. cit.*, p 1529.

the contract; uncertainty of contractor in estimating costs and return on enterprise; and possibility of skimping the work or disagreeing on its inspection and acceptance. To offset some of these factors short-term contracts are favored in mining; the Anaconda Company uses stoping contracts for one week only, and these may be terminated after one day by either party.

The practice of bidding monthly for contracts to perform stipulated tasks in certain parts of the mine has been carried on for hundreds of years in the tin mines of Cornwall. This custom of auctioning off the privilege of working a part of the mine has probably stood the test of more severe economic conditions than any other form of payment for labor; but it is, of course, established in that place by long tradition, and it is doubtful if it could be transferred to another country or implanted in any other race of people. Although this system of rewarding individual effort has worked well in these mines, it has been noted that the workers required as much supervision under this scheme as under any other, to insure the maintenance of standards of quality and quantity.

Task-and-bonus system.—The task-and-bonus method of paying wages is possible only where scientific management has been instituted and efficiency studies have been made to establish base rates for various kinds of work; it then becomes possible to arrange a scale of premiums to be paid for any results attained above the basic level. This method, like the contract system, permits the miner with initiative to earn more than the slow or lazy individual, and the company benefits by reduced overhead per unit of work. The bonus system does away with all of the disadvantages of the contract system except that of determining the amount of wages to be paid. "It may seem to some," says Tillson on this point,

> that the base rate should be the average productivity of labor at the time the premium system is initiated, but further consideration will indicate the unsoundness of this view. In the first place, the company must lose money if it pays a premium for all work in excess of an average and guarantees a minimum wage, for if no change is made in the productivity of the labor it is paying a greater total sum for the same amount of work. In the second place, temporary industrial or local conditions may cause the present operations to be an unfair index of the productivity which might normally be expected of labor. . . . The base rates should be established at a point which permits ready attainment by the industrious, but yet indicates an honest shift's work by an experienced man.[7]

[7] Tillson, B. F., "Increasing Efficiency in Mine Labor," *Engin. Min. Jour.*, March 11, 1922, pp. 400–402.

Aside from bonuses to individual workers, the idea may be applied in efforts to stimulate the performance of a gang or shop; for example, a special bonus might be paid to the workers in the metallurgical plant, based on a scale corresponding to the percentage of metal recovered. Such a plan, properly administered, discourages slackness in the ranks and promotes more careful attention, greater neatness, and a mutuality of interest between worker and operator. An indirect result might be a reduction in repair bills, since many of the workers would under it take better care of machines and make petty repairs themselves.

There are a number of varieties of bonus plans, depending upon the particular aim of the employer. A premium, for instance, may be placed upon speed in certain work when time is limited. In order to reduce labor turnover and inefficiency through absence from the job, bonus plans have been successfully instituted in certain mines, based upon continuous service; in one company, an employee with a perfect service record received \$100 at the end of a year, and for each additional year of continuous service an additional \$10 was paid until the maximum bonus of \$250 was reached. It may be noted that there is no reason why several types of bonus may not be in effect at the same time; a bonus on continuous service, it is clear, would not interfere with the attainment of a bonus based on the higher recovery of metals.

Other incentive wage plans.—There are several other types of incentive plan which have been used in mining. One of these is the sliding scale of pay corresponding to the current price of the product; under this plan the worker assumes part of the risk of the enterprise, sharing in a rise in prices and taking what amounts to a voluntary decrease in wages when prices are low, thus often making it possible for the operator to avoid a shutdown. Another means of securing the co-operation of workers is to offer shares in the company under exceptionally easy terms.[8] It should also be understood that any effort on the part of a company to increase the welfare or raise the living conditions of employees above the average is in reality a form of bonus or indirect wage.

Determination of suitable wage plan.—The advisability of installing any particular wage plan at a given mine or metallurgical plant is, of course, dependent upon local conditions, type of labor employed, and quantity and nature of work to be performed. These

[8] See Peele, *op. cit.*, pp. 1530–31.

varying factors should be studied as a problem in efficiency engineering, and experiments should be made to discover which plan will in reality be most effective in the situation. The technique of erecting standards of performance for various tasks has been mentioned in the previous chapter. The widespread acceptance and practical application of a new plan will, however, be possible only through the loyal and understanding co-operation of foremen and other supervisory officers.

THE EFFICIENCY OF LABORERS OF VARIOUS NATIONALITIES

It was stated in chapter 7 that total labor costs in districts where unskilled native workmen are employed are seldom less than in districts where only white labor is used, and that the expenses of training, supervision, and high turnover, which penalize efficiency, may frequently outweigh a low wage-scale. This is considered axiomatic by many experienced observers. Finlay states that in the districts of which he has knowledge,

> such as the Transvaal, India, and Mexico, where native labor is employed very largely at low rates, it is well known that costs are not lower than in the United States for similar work. It appears that where labor wages are very low there is little or no acquaintance with machinery, and the performance per man is correspondingly low. Where large numbers of natives, ignorant of all civilized mechanical appliances, are employed at a large plant, they must be supervised by white men who do little actual work and get wages higher than they do at home.[9]

The same opinion is reflected by Bain:

> Mining men, being accustomed to work in many countries with many sorts of labor, have long since learned that low-priced labor is not necessarily cheap. As to mines, at least, other conditions are usually more important than the nominal rate of wages, and workmen who receive small pay are usually worth what they are paid and no more. When the cost of extra supervision, extra housing, larger plant, slower speed, and other factors which go with "cheap" labor are taken into account, the gain is usually much less than appeared probable when the original estimates were made. There are many reasons for this, and not the least important is the deterioration that white labor undergoes when in contact with the colored. Standards of efficiency go down rapidly, and a feeling of caste promptly springs up which prevents the white man from doing the work to which he is accustomed at home. Even the crudest mechanic assumes the position of a boss and requires a native to do all the hard work. Since the white men as officers and

[9] Finlay, J. R., *The Cost of Mining,* McGraw-Hill, p. 48.

supervisors set the pace for all, the final effect of this spirit is reflected in the cost sheet.[10]

However, if cheap labor is not necessarily economical, neither is a high wage an absolute measure of efficiency of mine labor. The current wage in a given district reflects the condition of the labor market rather than the skill of the average worker; that is, in a camp where the prevailing wage rate is $8 a day, the miner does not produce twice as much as a miner of the same rank in a camp where the wage is $4 a day. Wages for the same class of labor are higher in more remote districts where the supply of workers is limited and living conditions are uncomfortable and expensive. When good workmen are scarce the miners do not exert themselves so much to hold their jobs as they would if, when coming off shift, they saw a long line of applicants ready to take their places.

Observations reveal, too, that in certain countries where the natives are accustomed to a low scale of living a management familiar with the customs of the country and the psychology of the native can develop, in time, a body of mine laborers that can perform, at a low wage, many operations as effectively as can the average white laborer in the United States. A rigid method of selection and training, as well as time and patience, are required to build up such a corps of native miners; but it is not impossible. The Chinese miner in Upper Burma after six or eight months' experience under a good foreman will drill just as many feet of holes or do just as much tramming on his wage of sixty cents a day as will an American miner in California at four dollars a day. The Turkish miner in the copper mines of Asia Minor after a suitable period of training is equally efficient. Almost all of the unskilled labor on the Rand is done by Kaffir "boys," and certain tribes of these natives, under proper supervision, are extraordinarily adept at mine work.[11]

Few Mexican miners of the old type, familiar with mining work for generations, are now obtainable, and the necessary employment of agricultural workers has many drawbacks; when the time comes to harvest the village crops it is almost impossible to hold them at the mine. The most successful results are obtained through placing much of the work on a short-term contract basis. The average worker has little vitality, seldom desires to improve his living con-

[10] Bain, H. Foster, "Problems Fundamental to Mining Enterprises in the Far East," *Bulletin No. 114*, Min. & Met. Soc. of America, 1921.

[11] See Carter, T. L., "The Kaffir Mine-Laborer," *Trans. A. I. Min. E.*, Vol. 39 (1908), pp. 419–50

ditions or to earn money beyond the needs of the moment, is over-fond of strong drink, and is accustomed to leave his work to observe the numerous fiestas and saints' days. Labor legislation in latter years has enacted such stringent governmental regulation of employment and workers' compensation that it is almost impossible for foreign capital to operate mines in Mexico, and the policy of permitting only a small fraction of foreign employees at a mine precludes the possibility of effectively supervising the work.

In the past many mining engineers in Mexico made the fatal mistake of failing to provide for the steady accumulation of a permanent labor supply when developing and equipping mines far from centers of population. Many nationalities are accustomed to migrate to districts where there is a chance of employment; the Mexican miner, however, will not travel more than a few miles from his birthplace except under strong compulsion. A miner living in the town of Parral, where there was not enough employment to keep a population of 20,000 above the starvation line, would not move twenty miles to take a job at newly opened mines at Santa Barbara. Five hundred laborers from the town of Guanajuato, brought to Santa Barbara, remained but a short time; at the end of three months no more than half a dozen of them were left, incompetents who in that time could not save enough money to purchase tickets back to Guanajuato—a place where people were unable to find work enough to keep alive.

Most of the unskilled, and much of the semi-skilled, mining labor in the United States is performed by workers of foreign birth or descent, although in recent years immigration restriction has greatly diminished the influx of foreign workers. The average native white worker prefers to find a job in places where modern machine methods have done away with the more laborious hand methods.

THE FUNCTIONS OF A PERSONNEL DEPARTMENT

The most obvious reason for the maintenance of a personnel department is the reduction of wasteful and costly labor turnover; yet rapid turnover is not so much an acute condition as a symptom of maladjustments in various places in the organization, and these can be corrected and a reduction in labor cost obtained only by going to the root of the difficulty and eradicating the true causes. To attain this end is the function of that division of the organization,

whatever may be its title, which is charged with the administration of sound policies for the heightening of human efficiency.

The personnel officer is of all the staff officers the one necessarily most active in promoting co-operation among all branches of the work. On the single matter of employment of workers he must be in close touch with all of the company's executives, from manager to shift boss, and must appreciate the points of view of both laborer and supervisor. He must know why men work and why they don't work. He must be able to harmonize many different attitudes and help each member of the organization to discover and understand the scientific possibilities and limitations of the work performed. A problem in sanitation, for example, may require the consultation and co-operation of the personnel man, the mine physician, the mine manager, and possibly a workers' committee. In short, the personnel man is the liaison officer between the two management functions of supervision and efficiency engineering.

Although the personnel division is primarily useful in attempting to raise the efficiency of labor, this task has so many ramifications that a number of duties, other than hiring workers, are ordinarily turned over to the staff officer charged with this responsibility. At a small mine one man may perform all these duties, or they may even be retained by the manager himself; while a large mining and metallurgical company may possess a large and highly organized personnel department performing, to a greater or less extent, almost all of the functions listed below.

Employment.—It should be understood that the employment functions of a personnel department should not weaken the old rule that no foreman or other supervisor should have a man under his direction who is not acceptable to him. The retention of a worker assigned to a part of the organization should be contingent upon his acceptance by the foreman. However, when a foreman is dissatisfied with a worker he should not have the power of discharging him on the spot but should send him to the personnel department, where the man's qualifications are reviewed and an attempt is made to place him in some other part of the organization. The employment powers of the personnel department are merely advisory; but the practice of hiring through such an office does much to counteract any charges that the foreman employs men through favoritism and has a hold upon them because they keep their jobs through his good-will.

The employment functions of a personnel department may include: knowledge of labor market, work requirements, terms of em-

ployment, and wages paid; selection of workers through interviews, references, physical examinations, special standardized tests, and trial periods; instruction of new employees; transfers and promotions; and maintenance of employment records and issuance of reports on the employment situation. It is often customary to interview employees who are leaving, in order to find causes of friction in the organization or, if the man leaving has been satisfactory, to let him know that reapplication at a later time will be considered.

Safety and health.—The personnel department frequently shares with the company physician the responsibility of supervising the safety and sanitary conditions of the mine plant and community—especially in the fields of worker fitness and disabilities, first-aid training, accident prevention, compensation payments, inspection of working conditions, and research on physical efficiency. Chapter 26 is devoted to this phase of mine management.

Training.—The vocational training of workers, and other educational endeavors of the company—such as bulletin-board information, the company library, classes for foreigners, and general educative work—may be carried on by the personnel department. In some communities the whole burden of providing schooling for the children of employees will fall upon the mining company. Training is dealt with in the next chapter.

Research.—The personnel department will devote much of its time to efficiency research, job analysis, and planning of improved methods, as discussed in the previous chapter. It may make standard specifications for each task, based on time and motion studies, fatigue studies, and wage plans, and will keep in touch with the growing literature of efficiency engineering.

Welfare and recreation.—Welfare activities may include promotion of such recreational facilities as employees' clubs, athletic teams, outings, and moving pictures, as well as promoting benefit and insurance schemes, co-operative purchasing clubs, thrift plans, and supervising company housing facilities. For a further description of welfare activities, see chapter 26.

Industrial relations.—The administration of industrial relations is an activity in which the personnel department—although it may have no direct authority—is, by virtue of its relations to all workers, especially fitted to serve in an advisory capacity to disciplinary officers. Conferences with shop committees or union officials, in con-

sultation with the mine management, may do much to adjust such questions as adoption and enforcement of working rules; employment terms, wages and hours; grievances, complaints, and discharges; and other problems of supervision.

The personnel division should also consider itself as a body to co-ordinate the various activities of the other branches; to keep executives informed upon its current activities and policies, and upon labor legislation and industrial movements in other places; to know at all times what the worker is thinking about; and, in general, to smooth personal contacts and build up a sound company morale.

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Chapter 25

Training and Discipline

Discussion of problems in supervision of personnel would not be complete without some consideration of the educational activities of the management of a modern mining and metallurgical company, and of the duty of foremen and other supervisory officers to maintain discipline and the principle of the fair deal. Some mention must also be made of a disciplinary problem which assumes great importance in the mining industry—that is, the stealing of ores and amalgams.

TRAINING AND EDUCATION OF PERSONNEL

The need for an efficient, permanent, and contented personnel, as has been said, leads the mining company into the field of education and vocational guidance. The problem of educating the children of the mining community also frequently devolves upon the company; and therefore many mining organizations must have a department concerned with the education and training of both children and adults.

The educational endeavors of the mining company may be said to fall into four classes: (1) development of young executives; (2) vocational training of skilled and semi-skilled workers, and breaking in new men; (3) general educative work, and classes for foreigners; and (4) the schooling of children in the community. Ordinarily, the responsibility for this work will fall upon the efficiency engineer or personnel man, but the mine manager should be in close touch with all developments in the educational program and should himself directly undertake the training of young engineers during their first contact with practical problems.

Training young executives.—Just as the education of a doctor is not complete until he has served a period of interneship under the eyes of men of professional experience, so the young engineer's university training must be supplemented by a year or two of proba-

tionary work before he may trust himself to exercise his judgment in the solution of critical problems. The continuation of the education of graduates of mining schools who have become employees is a not inconsiderable part of the duty of a mine manager. He should assist and encourage these young men to attain self-confidence in practical work, curbing and disciplining those whose bumptiousness may lead them into error. The mine manager may never become one of the stars of his profession, but he can at least always do one thing eminently worth while: he can exercise a powerful influence over the careers of the generation that must carry on the work in the future. His efforts in this direction will be generously repaid; a manager, in order to succeed, must have the loyal support of the members of his staff, and he can gain this only through an equally loyal devotion, expressed through painstaking interest in their professional advancement.

Many a promising career in mining has been wrecked because at some discouraging moment other roads looked rosier; slowness of promotion, low pay, and impatience sometimes lead men educated as mining engineers to become farmers, real-estate agents, or bankers. In such cases the legitimate inquiry arises whether these men were not deficient in that steadfastness of purpose which is one of the most fundamental traits necessary to a successful engineering career, and whether, on the whole, the profession is not benefited by their withdrawal from the field. When a young engineer says he is discouraged and thinks he has a chance to better himself by selling automobiles, it is best to urge him fervently to embark in the automobile business.

In attempting to carry on any policy of developing the usefulness of promising young engineers in a mining company, the manager will encounter certain difficulties, and must be prepared to meet them. The most obvious of these are as follows:

1. Some of the labor force at the mine may resent such apparent class discrimination as may be involved in close contact between a young engineer and a higher official. With this possibility in mind the manager may easily arrange to obviate any friction of this sort. Announcement of evening classes for all men who have completed certain prerequisites puts the matter on a business footing and leaves the critical ultra-democrat no cause for complaint.

2. In too many instances the coaching of young engineers is left to foremen and minor officials who have no interest in, or capacity for, the task; many of them, indeed, resent the request that they

disclose what seem to them precious craft secrets. A remedy would be to give additional pay to such foremen, or better, to require that instruction of young engineers be a part of the work of major staff executives.

3. Many graduates do not have the physique to compete with hardened laborers at certain posts. The management should see to it that a young engineer is not given work that taxes his strength too severely. The value of hard manual labor as a medium of technical education is questionable.[1] If the engineering graduate does not have a chance to work for a company which has a definite policy of breaking in new employees by methodically shifting them about in positions where they will rapidly gain experience in many fields, he will do well to take the first job offered, no matter how lowly, and work at it loyally and conscientiously. By working side by side with day's-pay laborers the young engineer gains an understanding of, and a sympathy with, the ordinary mine worker which may prove of inestimable value to him as he gains greater executive responsibility. Working during summer vacations is an excellent way to attain this experience. But few young men can put in a full shift at drilling, tramming, or shoveling without being so fatigued as to care only for sleep and food; when working under such a physical strain the mental faculties are held in abeyance, one ceases to observe, and may learn next to nothing about the implications of his work. Much of the belief that manual labor, and training that begins at the bottom, is an educative force is based on the fallacy that a man must do a thing himself in order to know whether or not it is done properly. Keen observation and logical reasoning will enable a person with a university education to pass correct judgment on a performance which he himself could not duplicate. For a young engineer to attain, for example, the skill of an experienced driller would require years of practice, and would be of comparatively little value to him in the pursuance of his profession.

4. Some young men will not appreciate the practical mining instruction that is proposed in this chapter, and will grow to expect special attention and prerogatives as their right. They suffer in consequence through a lessening of self-reliance, and from this attitude they drift rapidly into a lack of harmony with their associates. The management should take care not to encourage any expectation of favors. A limited amount of experience under a hard-boiled shift

[1] See "Mucking as an Educator," (edit.) *Min. Sci. Press*, May 27, 1916, p. 776.

boss is an important part of an embryo mining engineer's training; with the increasing mechanization of underground operations, any able-bodied young engineer can put in a full shift's work.

5. Many managers good-naturedly make a place for a young engineer and then, having pitchforked him into the job, leave him to sink or swim. This is a wasteful process in several ways: a waste through putting an inexperienced man into an important position, and a waste of an opportunity to heighten the value of the man to the company and the profession by systematically supplementing his education and giving it direction. The influence of the manager over the young employee is greater than that which a teacher can bring to bear upon a pupil, and results should therefore be more easily attained. Discipline can be enforced, and plain speaking indulged in, although judicious praise must not be forgotten. The interest of the apprentice in a subject is greatest at the time when he is confronted with it in the performance of his daily task, and this is the most suitable time to give him practical instruction and to refer him to sources of further information on the subject.

6. A young engineer during the first year of service in his profession is in most cases a liability to the company employing him; that is, he seldom earns his pay. Some cautious managers look upon his service as a financial loss and are unable to perceive that investment in proper training of recruits will almost always bring high returns when the period of development is past. Under any methodical system of training the honest and industrious young man will probably earn most of the salary paid him, and during his probationary period he will learn the fundamental lessons of loyalty and co-operation under capable leadership and will, as well, grow daily in his understanding of the company's activities and purposes.

7. Frequent shifts from one position to another are necessary in order to determine what the young man is best fitted to do and to enable him to obtain some practical contact with most of the departments of the work. A successful program requiring service in a dozen different positions during the first year has been outlined by Professor H. S. Munroe.[2] Following this plan, four months would be spent in the offices in various capacities, another four months at practical work underground, and the final four months at various parts of the metallurgical plant. These twelve months of training should enable a promising man to find his particular niche in the

[2] "The Apprenticing of Graduates at Mines," *Min. World,* Aug. 6, 1910, pp. 217–19.

organization, as he will during that time have come in contact with the work of almost every major staff official. He might then put in a second year as assistant in the department where he will be likely to prove of most worth, after which he would be in line for rapid promotion. The scheme can be carried out in detail only at a mine of considerable size, but the idea is capable of adaptation to a small mine with slight alterations.

One matter which is given little attention by the undergraduate but which must be taken up seriously when he is continuing his education in the field is the reading of current technical journals. A young engineer can live without the daily papers, he can thrive without the movies, but he should desert his profession at once and become a realtor if he proposes to try to get along without keeping thoroughly posted on the progress of the art of mining and metallurgy as revealed in the professional press. If necessary he may confine himself to one journal, but every issue should be read from cover to cover, including the advertisements, and thoroughly digested. Two journals are better than one, and three better than two. The mine management should see to it that its junior staff reads voluminously and understandingly. No technical man can find outside his special class publications the right intellectual food. Although there are a few exceptions, the usual textbook is several years behind the latest practices; these new ideas the student, in college or out, must obtain through the columns of the technical press. For example, when the first book on concentration of ores by flotation was written, the technical press had printed hundreds of articles concerning the process, which was in operation at dozens of mines and was used in treating a million tons of ore a year.

The topic of reading technical journals naturally leads to the idea of writing for them. Nearly every engineer, young or old, has the opportunity to make observations which, if duly recorded and presented, would be of great value to others engaged in the same sort of work. There is no end to the subjects in mining and metallurgy upon which excellent articles may yet be written. To cite but one instance, there has never been published a complete time-chart of the activities of any employee working at a gold mine in the state of California, and such an account would assuredly make interesting reading. Even if notes and sketches made during the day's work are never published, they will give the engineer a fund of information upon which to draw in the future. The mine manager should therefore make sure that the younger members of his staff

regularly make use of the following records: notes on daily work; sketches of ore formations, openings, terrain, equipment, new devices, etc.; written queries regarding anything not understood, which may be explained at a later time; and rough calculations concerning the task in hand.

Mining companies should make it possible for members of their permanent staffs to visit distant mines and metallurgical plants and thus to secure the benefit of contact with other minds engaged in solving similar problems. The practice of sending engineers to plants all over the world has been sedulously followed by the Japanese, and it is to this that they owe much of the progress they have made in adapting Western methods to their own purposes. A like endeavor of mining companies is to encourage the attendance of staff members at meetings of technical societies and industrial conferences.

Vocational training of personnel.—The subject of vocational training of workers naturally divides itself into two parts: the breaking in of new men and the extension training of subordinate workers to broaden their knowledge of their jobs, thus making them of greater value to the company and paving the way to promotion and higher wages.

Training new men. When a recruit is needed for mine or mill, it is too often the custom to choose a man from the daily "line-up" with little regard for his qualifications, put him on the job at once, and, if he cannot learn to hold it within a few days or a week, to pick another man and let him go through the same wasteful trial-and-error method of learning. Such a procedure inflicts a wrong on both the company and the man. Almost every worker in the company should have a trained understudy who is capable of stepping in at any time and carrying on his work. Instruction of understudies and of new workers will be about the same, and should be given systematically and explicitly.

In the first place, the duties of the man at a given post should be stated in a typed manuscript, which also gives a detailed description of all the operations to be performed and the reason for each. Conclusions based on time-motion studies, if they are available, should be included in the instructions. The recruit should be given ample time to read the manuscript and ask questions concerning the work, and should then be put through a short oral examination upon its terms by the foreman or superintendent. He may then be set to work, under the supervision of the instructor. The chances are that he will

have to be shown several times the exact method of performing some operations. Continual reference to the written instructions should accompany manual demonstration. After the candidate has worked at his task for a day or two he should be given another oral examination, and if defects are noted in his manual operations they should be corrected as early as possible. The examinations and instruction cannot be left to a foreman of the old-fashioned, uneducated type, but only to one who has had the privilege of taking vocational training and is familiar with the use of modern efficiency methods.

A new man should learn the names of all other workers with whom his work brings him in contact; and, in general, all members of the organization should address each other by name. Too often a worker's personal identity, and the self-respect that goes with it, are lost; his response when being addressed as "Hey, you!" can easily be imagined. It is also a wise plan to encourage a worker to identify himself with his job in some manner; although one does not need to resort to absurd titles, it is a good thing if a man can feel that he is not simply a mine hand but is "trammer on No. 3 level" or "table man at the concentrator."

Vocational extension courses. The most successful type of vocational training for mine workers has been a series of lectures given one or two times a week (the afternoon lecture repeated in the evening, to accommodate both shifts) to men who wish to better themselves by learning more about their trade. At every mine there will be men who will look the gift horse in the mouth and will not see what they have to gain by adding to their technical knowledge; but those who do register in such an extension course will be workers of ambition and unusual force of character, and will therefore strive eagerly to educate themselves so that they may be given consideration when positions as shift boss or foreman are to be filled. Not all mining men can be engineers and managers, but there is no reason why the shift boss and many of the workmen under him should not have a broad knowledge of the technique and fundamental theory of their daily work. The influence of such vocational training will extend far beyond the men who have taken the course; for these men will spread their knowledge among fellow-workers on the job and will thus act as an unofficial teaching corps.

The lectures may be drawn up, mimeographed, and sent to the men in the course three or four days ahead of time, so that they may be read and used as a basis for questions and discussion in the seminar that should follow the brief lecture. The series of lectures

should be so arranged that they can be taken up at any time and followed through the entire cycle. An excellent course of forty-three lectures, given throughout a ten-month period, is described by Willis and Young.[3] The series, issued in pamphlet form, is given by Copper Queen officials, and covers such topics as tools, breaking ground, sampling, explosives, safety. mechanics and applied mathematics, practical geology, elementary economics, problems of supervision, and company policies. A board, consisting of certain mine officials and workmen who have successfully completed the course, gives periodic examinations on the subject-matter of the lectures, and if the candidate passes and also has had two years' practical experience he is given a certificate of proficiency as a "skilled miner." Such certificates, comparable to the "papers" of able seamen, are of value in any mining community. It is understood that such qualified men will have preference when posts as shift bosses are to be filled.

The methods used in teaching adults are obviously very different from those applicable to school children. The men are presumed to know the practical side of their work, and it will ordinarily not be necessary to require them to take notes on the lectures or to do any preparatory work aside from reading the assigned lecture. Drawings, charts, and lantern slides will be suitable teaching aids. The director of the course—the efficiency engineer or personnel man is a likely possibility—should know something of teaching methods, should be able to draw out the latent powers of expression in those men who have been chosen to give the various lectures, and should help them in every way to present their ideas effectively at the discussions. Mine officials of all grades, as has been indicated, make the best lecturers in a course of this sort, for they already hold the confidence of the men; college professors are suspected of lacking practical ability, and very young engineers of lacking a background of experience.

The practice of holding periodic conferences for foremen is another excellent method by which the mine executives may perform educational work of great value. Practical problems arising from the daily work furnish excellent opportunities for giving useful knowledge to the men on the job, and valuable ideas may arise through free discussion in such meetings.

Occasionally a worker or foreman will seek the advice of his

[3] Willis, Charles F., "Educational Methods at the Copper Queen," *Trans. A.I.M. & M.E.*, Vol. 63 (1920), pp. 607–16; Young, George J., "Practical Mining Course at the Copper Queen," *Engin. Min. Jour.*, Dec. 18, 1920, pp. 1171–74.

superior on the question of taking a correspondence course with the intention of fitting himself for a position of more responsibility. Such ambitious endeavors should be encouraged without holding out any definite promise that promotion will follow the completion of a course in an approved correspondence school. (It should be noted that the first-rate schools of this sort in the United States may be counted on the fingers of one hand.) The adviser can, of course, point out that further education may lead to betterment of position elsewhere, even if the posts at the mine where the man is working are limited. The solitary application required to complete a correspondence course demands a singleness of purpose and a tenacity which few men possess; and the difficulties of such a path should not be glossed over. Younger men should ordinarily never be advised to eke out their education with courses by mail; if they wish technical training it is usually possible nowadays for them to obtain it through attendance at recognized schools and colleges.

Another large class that may be greatly benefited by proper vocational training, in collaboration with practical work on the job, are high-school and grammar-school graduates who intend to follow mining and metallurgy as a trade. There can be no doubt that the mining industry has suffered through the replacement of American youths by foreign-born miners, and almost never nowadays does a miner's son look forward to following his father into mine work; but the curtailment of immigration will inevitably cause a demand for able and ambitious native-born workers. The vocational training of young men who have taken proper school work to fit them for industrial trades should receive the support of mining and metallurgical companies that realize the value of obtaining alert and intelligent recruits, who are ready to fit themselves for positions as foremen and shift bosses.

Classes for foreigners.—It is customary in the United States for many mining companies to supplement their general educational work by offering classes in which foreigners may learn the English language and fit themselves for naturalization as citizens. Such "Americanization" work is of practical worth not only in increasing the general welfare of workers but also, through assisting the foreign-born element to understand spoken orders and written rules, will permit better supervision and more efficient operation and aid in the prevention of accidents and the enforcement of safety regulations.

A similar activity is for a company in a foreign land to conduct

a class for mine officials, who, under the guidance of a capable teacher, will increase their command of the language of the country and thus permit greater co-operation with the native workmen and others with whom the company carries on business.

Education of children in a mining community.—The duty of providing for the education of children in the mining community frequently devolves upon the mine manager. Every mine operator knows that a married miner is a better worker than a single man; and a good school system is one of the best means of attracting families. This will probably involve the company in some additional expense, but money spent for schooling of employees' children will in the long run be well invested.

The later years of study in a public-school system in a mining camp may easily be developed into a vocational school. If a boy who has reached the age of sixteen years is encouraged to work for the company three days a week and carry on vocational studies three days, his education will be rounded and he will ordinarily develop into first-rate material for jobs of some importance. Such methodical vocational training leaves little time for hooliganism or acquisition of the loafer habit.

Closely allied with formal education of children is the provision of decent recreational facilities; and even though some mining camps do not have a length of life to warrant any great expenditures for recreation, in most communities playgrounds and picnic grounds can be maintained at a moderate cost if the mining company plans such activities from the first. The tendency is for a mining town to grow like a repulsive mushroom until it is too late to plan for its inhabitants a sane, congenial, and healthy life. Sometimes a blessing disguised in the shape of a fire wipes the slate clean; and such an opportunity for the management to provide safe and pleasant playgrounds and other recreational facilities should not be overlooked. The ways in which a mining company may foster a wholesome social life for the adults of the community will be mentioned in chapter 26.

DISCIPLINE: THE FOREMAN

The efficiency of mine workers will be largely determined by the efficiency of those supervising the work, from the mine manager to the shift boss. The speed, thoroughness, and attitude of laborers toward their work will correspond to the attitude of the foreman, the representative of management with whom they are in closest contact.

The foreman, as has been said, should possess in some degree all the qualities that go to make a good mine manager. He should know his job and have a proper pride in the work, and should be especially capable of dealing with men and training them to attain greater efficiency. The foreman should never be given responsibility for the performance of a task without at the same time having authority to command the required resources. His methods should be systematized as far as possible, and he should hold frequent consultation with the staff officer in charge in order to deal with any unusual situations, as well as to make periodic checks on the progress of the work. Considerations of safety and economy should always take precedence over speed of performance.

In the work of mining, which is subject to certain unusual risks, a firm discipline should at all times be maintained. Young says on this point:

> Obedience to orders by the workers is essential in the operation of a mine where dangerous conditions prevail. A sufficient number of foremen, shift bosses, and bosses is necessary in order to cover the working places adequately. They should be required to report all infractions of regulations as well as careless or incompetent workers. The breaking of a safety regulation should be brought to the immediate attention of the worker and he should be warned. A repetition of the offense should be met by a temporary layoff and a third infraction by discharge.[4]

The wise use of the principle of the fair deal is the final test of a good foreman. He should give credit to any worker who makes useful suggestions; in some plants a suggestion-box is readily available and all worth-while ideas are rewarded by a small bonus. No foreman should ever refuse to consider with patience any legitimate grievance. His authority should be used only to further the interests of the company and never to satisfy any selfish or wrong-headed desire to inflict his will upon a fellow-worker.

STEALING IN MINES

An ever-present disciplinary problem in mines where rich ore is to be found in easily recognizable form is the type of stealing euphemistically termed "high-grading," "glomming," or "specimen-hunting." At various times, camps like Goldfield, Grass Valley, Cobalt, Kalgoorlie, Bendigo, and Ballarat have suffered incursions of this sort amounting to large proportions of the mines' yields. It has been stated that in one year fully a million dollars' worth of ore

[4] Young, George J., *Elements of Mining*, McGraw-Hill, p. 559.

was stolen from the Goldfield Consolidated mine in Nevada. The loss from stealing ores and amalgams may easily be so large at some mines that a property which would otherwise operate at a profit becomes impossible to maintain.

Aside from mines producing precious stones, gold and silver mines are the chief victims of high-grading, because the values are usually found in such concentrated forms that a man can carry away, with little fear of detection, a considerable amount of such materials as rich quartz and rich tellurides of gold and silver, as well as amalgams from stamp mills, precipitates from cyanide plants, bullion, and buttons from the assay office. Rich silver sulphides and chlorides will not be susceptible to great losses unless the pilfering is on a very large scale; this also applies to copper and lead mines, although at the Broken Hill the unique mineral specimens were frequently pocketed by the miners and traded for drinks in town. Tin ore in Cornwall has been traditionally subject to theft, even though it may have been worth no more than five cents a pound; for in a country where wages are low even a few cents a day added to a man's wage may become an incentive to dishonesty.

In some communities a moral laxity condones this form of stealing when any other form would not be tolerated. It is sometimes felt that native elements in the rock are a sort of free supply, of which a portion belongs to the man who first sees it and has the cleverness to get it away, and that it will not be missed by what are pictured as the opulent stockholders of a large company. Evidence of theft is always difficult to obtain, and the majority of honest folk naturally resent any methods which presume to put all workers under surveillance. Moreover, the high-grader usually spends his ill-gotten wealth among local tradesmen or squanders it in neighboring dance halls and gambling-houses, whereas much of the proceeds from the ore turned out by the mine is usually spent elsewhere. Such warped and devious logic often hinders efforts of mine managements to restrain high-grading and apprehend offenders of this type.

The moral effect upon a mining community where there is general suspicion that stealing is widespread is fully as disturbing as is the actual loss. Distrust is in the air, and no one can be sure of his neighbor. The management should take active steps to wipe out this form of thievery and bring such charges into the open. At one mining camp the loss was trivial but the fear engendered by gossip was enormous. Finally the manager traced all the charges to an old miner who in his cups was accustomed to babble mysteriously

of his stolen hoard. Upon examination this proved to consist of a few cans of contaminated amalgam salvaged from the ashes of a mill that had burned down—utterly worthless stuff, which could not be reclaimed. This discovery and its announcement at once swept away the general misgivings.

All sorts of workers, from the ignorant foreigner to the native American, may engage in high-grading. Indeed, the latter are apt to be more successful in their efforts and more difficult to detect, although they suffer comparatively more when conviction brings disgrace to themselves and their families. The ignorant miner will usually confine his operations to bonanza ore, while the more calculating worker may figure that by carrying off five pounds of lower grade ore worth fifty cents a pound he will be almost doubling his wages.

Methods of stealing.—Ore may be removed from the mine by underground workers who conceal it in their pockets, under their armpits, in dinner buckets, in the cuffs of overalls, and even under wigs and inside wooden legs and elsewhere. Sometimes large rich chunks are concealed in cap-boxes, or in sacks supposed to contain ore samples for assay; or they may be secreted in cars of waste, to be later recovered from the dumps. Rich tellurides have been crushed and mixed with water and applied to the miner's bushy head of hair, to be washed out later. A miner once stated that he had carried in his hair ten dollars' worth of ore a day from the Camp Bird mine, and that once the miners uncovered a knife-blade stringer of sylvanite which was "glommed" for weeks before the owners learned of it. A body of rich gold quartz encountered in the low-grade silver ore at the Grand Prize mine at Tuscarora, Nevada, was similarly concealed from the management. Diamonds have often been swallowed by workers, to be recovered later; as a protection against this practice the native "boys" at Kimberley used to be given a strong cathartic and closely confined for three or four days before being allowed to leave their compounds. In the silver mines of Potosí, native miners have been known to sew rich silver minerals in a leather ball an inch or so in diameter, to be then concealed in the rectum; such balls are to be seen in a museum at Arequipa, Peru.

Ore is sometimes stolen on a large scale and buried underground in the mine, even when there is little chance that the thief can ever recover it. He hopes that things may so shape themselves that he can later get a lease on that part of the mine and retrieve his cached pilferings.

Disposal of stolen gains.—The high-grader can rarely send his metal to the mint without committing himself, and will not ordinarily go to the great trouble to steal unless there is some other market for his ill-gotten gains. He must therefore have a confederate to market these for him without attracting attention; and control of stealing in a large district must be aimed at such accomplices or "fences," as is the governmental supervision of "I.D.B.'s"—illicit diamond buyers—in the South African diamond districts.

Rich metal ores are frequently disposed of through "fences" disguised as assayers. In Goldfield at one time there were at least twenty-five of these fraudulent assay offices, and at Cripple Creek a number of them were dynamited as a violent measure of protection. An assay office run by a man of little education may at once be suspected of being a "fence," and the quality of the assaying done in such an office should be tested by having samples submitted to it by a person not obviously connected with the staff of the mine. If one of the samples submitted is extremely rich, the reputed assayer may betray himself through the questions he asks concerning its source.

Another method of disposal is as follows: an ore thief or "fence" will purchase an abandoned mine or locate a claim in the vicinity of a rich mine and do a little development work from time to time to keep up the sham. Then he will take the ore he has stolen from the rich mine, or ore that he has bought from thieves, and ship it boldly as the product of his own claim. Such a plant which was run at Kalgoorlie at one time was equipped with a ten-stamp mill and marketed several million dollars' worth of pilfered ore.

A more modern method is for the illicit ore-buyer to visit rich mining camps at night with motor trucks, collect stolen ore at a low price, and be, at daylight, such a long distance from the mine as to evade suspicion.

Thieves may take the rich ore, grind it in a mortar, pan out the metal, and bury the tailings in the garden or cellar, or where quartz sand will not attract attention. When the thief takes his annual vacation he may be able to carry off a considerable amount of rich material resulting from these operations.

An amalgam thief who was too timid to trust anyone buried his stolen amalgam in his garden for a period of several years. He did not squeeze it dry enough, however, and a heavy rain washed some quicksilver down across a footpath, where it was observed by one of the mine staff. Careful prospecting to determine the source of

this providential supply of a commodity so useful around a gold mine led the manager, finally, to the stolen hoard.

Methods of prevention of stealing.—Aside from the energetic prosecution of "fences" of various kinds there are other methods by which the management may attempt to reduce stealing, although there can never be any assurance at a rich mine that all high-grading has been eliminated.

The first step in protection is to choose staff subordinates of whose honesty there can be no doubt. Choose the mill, mine, and smelter foremen on the same principle, because there cannot be any great loss from stealing if all the foremen are honest. The working force in contact with tempting opportunities should be family men, if possible; a married man, even if a foreigner, should be preferred to an American wanderer, for there is a perambulating type that prefer to work as muckers or trammers at a rich mine and who do not depend primarily upon wages for their livelihood. Incidentally the mine manager should recognize that miners of certain breeds should be watched with unusual care, for there are generations of ore-lifting proclivities in their blood.

A second step is the construction and operation of a well-ordered change house, which, aside from being an excellent sanitary arrangement, is a valuable check on possible stealing. It should be the only entrance to the mine available for the workers. Surface raises or ventilating shafts should be barred with grids of steel rails and should be frequently inspected. When coming off shift the men should remove their working-clothes, take showers in plain sight of the change-house man, and then pass into another room where they don their street clothes. Dinner buckets and all other containers coming out of the mine should be examined.

An attempt to introduce a change house at a mine which has never had such a convenience will always bring on violent protests and sometimes a strike. It is therefore a good plan to install a change house early in the history of the mine. If this is not done and protests against later installations are extreme, there is nothing for it but to shut down the mine, build the change house, and hire a new labor force.

Another valuable method of control is to have on the payroll a properly selected staff officer, who is sometimes called the "specimen boss," although he may have no other title than mine surveyor, mine sampler, or geologist. He will usually be a young engineer whose ethical standards are known to be high. It is his duty to watch carefully, in all parts of the mine, for the appearance of high-

grade mineral, and when it is likely that such spots will be opened up he should be the first man at the face after a blast. He then looks at the fallen rock and the face for specimen ore, and if any is found he will call the mine foreman or some other official, collect this mineral, and deal with it as circumstances demand.

Some mines have put their men on a profit-sharing basis for the purpose of lessening stealing. There does not seem to be much that can be said in favor of this plan. Although a small bonus may make the workers more watchful for looters, it will do little to discourage a determined thief.

The law gives the mine owner little protection against ore-stealing. It is difficult to prove that contraband ore was taken from a certain mine, and it is difficult to get juries to convict an offender. The bad moral effect of an absurd decision handed down some years ago in Colorado, that ore was real estate and could not therefore be subject to petty theft, has permeated many mining communities to the detriment of justice. In some countries the authorities will give the mining company a number of special policemen if the company will pay their salaries. This is a valuable adjunct to other methods of control. California has recently passed a law which requires bonding and licensing of any ore-buying agency which does a gross business in excess of $500 a year, and such legislation has had a good effect. It has also been proposed that there should be a federal act to control ore-stealing, which would throw high-grading cases into federal courts and do away with the possibility of local laxity in enforcement. However, since the withdrawal of gold from circulation and the limitations on its possession there has been a noticeable decline in high-grading.

No engineer should ever let any specimen ore stick to his fingers; if he wants to keep a sample of this rich stuff, he buys it.

"Gold poachers" and "marauders."—In the Russian Empire before World War I, the incapacity of most prospectors to comply with laws respecting mining claims caused the growth of a large class of roving and enterprising free-lance miners and prospectors called "gold poachers" (*hishniki*). Not only did this class of men take gold illicitly from government lands, but when employed by a mining company they stole all the ore they could. The total amount of gold illegally mined in the empire was set at from two to four million dollars annually. To prevent the smuggling of this gold into China the large companies were accustomed to buy the ore from the thieves at a price higher than that offered by illicit buyers; in one year, the company operating the Lena gold fields paid almost half

a million dollars ransom for gold stolen from it by its own employees.

A type similar to the Russian gold poacher is the "marauder" of French Guiana, a prospector or placer miner who works any gold-bearing territory he can find, regardless of its ownership. To put himself nominally under the law he obtains a permit to work a certain claim in the back country; although he probably never works on his concession, he ordinarily keeps to the general district for which the permit is issued. He is usually an expert and hard-working prospector, and may be regarded as an important element in the discovery and exploitation of deposits in the interior of Guiana.

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Chapter 26

Safety, Health, and Welfare

A working force cannot be efficient if its physical welfare is neglected. If the plant offers constant hazards to life and limb; if sanitary precautions are neglected and disease spreads among the workers to incapacitate them and disrupt the smooth operation of the organization; if there is widespread ignorance of what steps to take in the emergencies that are sure to arise in an industry more hazardous than most; if the men are poorly housed, fed, and clothed, and are cut off from the normal social and recreational outlets in their leisure hours—then there can be little wonder if the mine is producing but a fraction of the output that might reasonably be expected. For some time mining men have recognized that it is not only a humanitarian duty but a fundamentally wise business move, and sound economics, to invest a part of the profits in guarding their personnel from preventable accidents and diseases and in building a better industrial morale by increasing the welfare, comfort, and contentment of the mine worker and his family.

MINE ACCIDENTS AND SAFETY ENGINEERING

Mining is a hazardous occupation. The latest available statistics[1] show that the annual death rate in this industry in the United States is 80 per 100,000 population—this is far higher than the rate for any other country in the world and more than double that for most mining countries. Of all the main industries in the United States, mining has by far the worst accident record: in 1929 the accident frequency in mining was 74.43; the second most hazardous industry was meat-packing with a rate of 55.94, and construction came third with 50.41. Although metal mining is not as dangerous as coal mining, the accident frequency rate for metal mining of 52.16 for 1929 was higher than that for all but one of the main

[1] Harrington, D., "The Importance of Discipline in Mine Safety," *U.S. Bur. Mines Infor. Circ. 6558,* March 1932.

industries for which figures are available. There has been a reduction in metal-mine fatalities between 1911 and 1928 of about 37½ per cent; this is in the main a result of organized safety-engineering work, and reveals the truth that deaths and injuries in this occupation may be appreciably reduced by a program of safety education and by rigid supervision. The old idea that mining was inherently a dangerous occupation and that nothing could be done to improve conditions has gradually given way to an appreciation of the fact that safety education can be effective in protecting lives and reducing accidents, thus cutting down the tremendous waste and inefficiency and suffering entailed by careless working habits. Although "scare" methods can seldom frighten a man into taking necessary precautions, but will on the contrary sometimes stimulate him to acts of bravado, a rational program of true education and training of all workers in safety methods, enforced by supervisors through rigid discipline, will be a true measure of mining economy.

The cost of metal-mine accidents.—As to the cost of mine accidents, F. S. Crawford says:

> Even though industrial operations were not compelled to pay compensation, and even if the management were not moved by humanitarian motives to try to stop accidents, it would pay many times over to carry on accident prevention work vigorously and continuously. . . . . Accidents cost money far beyond the medical bills, compensation, and insurance premiums paid; in fact some authorities now hold that the ultimate cost of accidents is four or five times the amount paid out in compensation, medical cost, and insurance.[2]

The financial loss to miner and employer through mine accidents has been ably estimated by the United States Bureau of Mines:

> In the metal-mining industry, in a recent typical year, 430 men were killed and 30,350 men received lost-time but non-fatal injuries as a result of accidents. An average of 114 days was lost for each of these fatal and non-fatal injuries, again computing a fatality as 6,000 days' lost time. This is equivalent to 3,523,944 days' time lost due to accidents; or, at $5 per day per man, to a wage loss of $17,619,720. Again, deducting one-ninth of this figure for compensation paid, the metal miner loses in wages annually about $15,700,000, or about $122 per individual. This average loss per individual includes the cost of fatal accidents reckoned at 6,000 days, or $30,000, but even if the loss in time due to fatal accidents be deducted, the average cost of each metal miner each year for non-fatal accidents is about $32.

[2] Crawford, F. S., "The Cost of Accidents to Industry," *U.S. Bur. Mines Infor. Circ. 6333,* Sept. 1930.

Estimating the loss to the metal-mine employer as about the same as that to the employee, the annual cost of metal-mine accidents to the employer is about $15,700,000; to employer and miner the total reaches $31,400,000.[3]

The safety engineer.—The assumption today is that the management is fully responsible for all injuries to workers, since it lies with the employer to maintain a continuous and organized drive for safety and since he has the power to discharge recalcitrant workers who repeatedly expose themselves and others to needless risks. It therefore devolves upon the general manager to charge himself with the establishment and direct promotion of an effective program of safety education and inspection. He may delegate the performance of this work to a suitably trained staff officer; the efficiency engineer may be chosen, or an office with the title of "safety engineer" may be created. This man will devote himself to inspecting all possible danger spots in the mine and plant; to co-operating with safety committees in various parts of the organization; to keeping informed upon safety literature and to carrying on a perpetual educational campaign among workers; to co-operating with agencies such as the Safety Division of the United States Bureau of Mines, the National Safety Council, and state bureaus and inspectors; to heading all rescue work, first-aid instruction courses, and safety-first meetings; and to drawing up and enforcing a written code of minimum safety requirements for all work at the mine and plant.

Ideals for a mine safety department.—Proper and attainable aims for the safety department of a mining and metallurgical company may be listed:

1. *Reduction of death and injury rates for mine and plant.* The single purpose of a safety department, to which all its activities should be contributory, is the reduction and elimination of all possible hazards to human life and health and physical capacity through the promotion of preventive and defensive measures. A permanent, organized vigilance is necessary, as well as an active educational campaign reaching every worker. Frequent inspections should be made, and all construction and operation should be carried on subject to the approval of the safety officer. When accidents have occurred, a board of inquiry made up of employees should examine into causes and make recommendations for future prevention. Exact records should be kept as the basis for safety research as well as to enable

[3] "Financial Loss Represented by Mine Accidents," *Engin. Min. Jour.*, Dec. 28, 1929, p. 1003.

the calculation of the cost of accidents to the company, the worker, and the industry.

2. *Education of all workers in safety methods and their importance.* Every possible medium should be used to spread among all employees—bosses as well as laborers—the gospel of "safety first." Posters, bulletins, and charts should be posted where they will gain the attention of workers. Frequent meetings of various worker groups may be held, attendance being compulsory. Moving pictures (obtainable from the National Safety Council and the Bureau of Mines) can be exhibited and short talks can be given by company officials. If such a meeting is held immediately after an inspection of the part of the mine in which the group is employed, this inspection may form the topic of discussion and points at which improvement could be made may be noted. Demonstrations of safety devices and methods should be frequent, and first-aid contests, rescue contests, and other exhibitions may well fit into the programs of gala days. Special conferences and training groups for foremen and bosses will be found effective.

3. *Requirement of knowledge of safety rules and first-aid.* A complete code of safety rules should be drawn up and printed in booklet form, and every employee should be required to pass an examination on its contents and to sign an agreement that he will abide by these rules. Penalties for infraction of each rule should be stated; ignorance of the rule is no excuse, but rather an aggravation of the offense. The requirements should go far beyond the state safety regulations which must be posted in various parts of the property, since no state mine-safety rules are adequate or up-to-date. (One of the best company safety codes for metal mining is the pamphlet issued to all workers of the Phelps-Dodge Corporation.) The company should also strive to give a minimum course in first-aid to every employee; such training not only enables workers to treat injuries and save lives after accidents have occurred, but it is known that a knowledge of causes of injury leads to more watchful habits and to greater precautions. New employees should be subjected to rigid physical examinations to detect disabilities that would affect their working efficiency and safety; before starting work they should pass an examination on the safety code of the company, and should take the course in the first-aid during the first few days of their work.

4. *Disciplinary enforcement of safety regulations.* The mine operator, as has been said, is in a position to enforce a rigid safety code through his disciplinary officers, and all infractions should be

penalized by warnings, fines, and, if offenses are repeated, dismissal. As Harrington says:

> Here is where intensive supervision and discipline come in—and by discipline is meant not the utilization of "hard-boiled" methods of handling men but rather the establishment of common-sense, up-to-date regulations, seeing that they are transmitted to the men, and finally insisting that these regulations be obeyed and without reservation or delay.[4]

There should be enough shift bosses to permit inspection of every working at least twice a day; one boss to every twenty or twenty-five men is a good ratio to maintain. Special attention in transmitting orders and giving safety training must be devoted to men who cannot read or who understand only a foreign language.

5. *Use of safety devices and standard practice.* Before a mining company can expect a high degree of co-operation in safety on the part of its employees it must first be sure that its own conscience is clear. In other words, every effort should be made to put into effect the mining methods least productive of hazards; to see that all construction and operation has the approval of the safety engineer; to refuse to carry on work at a dangerous speed; to install safeguards on machines and other equipment; to make sure that the mine is well ventilated and that openings and shafts are guarded; to establish refuges, well-equipped first-aid stations, and repositories for explosives; to inspect equipment, especially electrical lines, at frequent intervals in order to remove hazards; to require strong and well-built timbering in order to prevent rock falls and cave-ins (falling rock is by far the greatest single cause of injuries and fatalities in mines); and to furnish workers with and insist upon the use of such special protective devices as goggles, hard hats, safety lamps, respirators, safety shoes, and the like.

Trained fire-bosses may be placed at strategic points, and fire-drills should be held every month or so; this training will be of value in saving lives during disasters such as floods and cave-ins. The fact that metal mines are not as greatly susceptible to fire disasters with great loss of life as are coal mines has probably caused a feeling of false security and relaxation of vigilance, whereas as a matter of fact, no mine is free from the constant threat of fire and consequent loss of life and property, the latter frequently amounting to hundreds of thousands of dollars. The passing of the candle as the sole means of underground illumination has diminished the incidence of

[4] Harrington, D., "The Importance of Discipline in Mine Safety," *U.S. Bur. Mines Infor. Circ. 6558*, p. 7.

fire in many mines of the United States. According to the most recent figures[5] at least three-fourths of metal-mine fires are started by electricity, open lights, smoking, and flame used for heating or other purpose underground. Other hazards commonly encountered are explosives, spontaneous combustion (from timber splinters or bark, stored hay or manure, carbonaceous shales, pyritic ores, oil waste against timber, etc.), gasoline engines, sparks from surface fires or locomotives or steam boilers, friction, and ignition of stored oil or grease. Burning timber and certain sulphide ores may give off a quantity of poisonous fumes and gases that will kill scores of people; the greatest danger to life in a mine fire or explosion is the ensuing generation of gases such as the deadly carbon monoxide, and respirators should always be used by rescue crews. Mines using "permissible" explosives[6] seldom encounter fires started by faulty blasting materials. Instructions for the prevention and fighting of mine fires and explosions may be found in Peele's *Handbook,* pp. 1620–39, and in references appended to the paper by Harrington just cited. Fireproofing of shafts and timbering by concrete and gunite is recommended, and standard fire-fighting equipment should be installed. Stench liquids, such as ethyl mercaptan (C_2H_5SH), injected into the main compressed-air line at the surface, will form an effective alarm to miners at the working-places. A simple record system at the entrance to the mine should be kept so that it is possible to check the presence of all persons underground at any time.

6. *Establishment of safety contests and bonuses.* Safety demonstrations, and contests between mines or mine departments to achieve record periods without lost-time accidents, should be encouraged by mining companies. Recognition of good safety performance through the payment of bonuses or some other form of reward should serve as a counterpart to the penalizing of infractions of the company code.[7]

HEALTH AND HYGIENE

To insure that the working force of a mine attains a high degree of health, physical comfort, and well-being, it is necessary to enforce

[5] Harrington, D., "Metal-Mine Fires and Ventilation," *U.S. Bur. Mines Infor. Circ. 6678,* Jan. 1933.

[6] See "Active List of Permissible Explosives and Blasting Devices Approved Prior to June 30, 1930," *U.S. Bur. Mines Rep. of Investigations 3025,* July 1930.

[7] See Harrington, D., "Bonuses to Encourage Safe Work and for Work Safely Done," *U.S. Bur. Mines Infor. Circ. 6625,* June 1932.

certain sanitary precautions and to undertake measures against the possibility of contracting certain diseases and disorders to which mining men are particularly liable. Disease is no respecter of persons, and all members of a community are equally susceptible to the evil effects of unhygienic conditions. The responsibility of the management to make every effort to prevent, check, and treat disease and to maintain sanitary and decent living conditions cannot be denied.

Housing.—It is a shortsighted policy for a mining company to neglect the comfort and physical welfare of the community population. It is probably true that the total cost of a proper housing program would be returned to the company within five years in added efficiency, contentment, and permanency of the working force. The company should take the lead in providing clean and comfortable surroundings in the mining camp, although it should avoid any hint of paternalism.

A considerable amount of money may need to be spent in the erection of houses for employees; this is an item of capital expenditure often overlooked when estimating the original cost of equipping a mine for operation. Rentals should be adjusted to attract a good type of laborer, especially men with families, rather than to obtain profit on an investment. The houses need not be luxurious, but they should be designed for cleanliness, convenience, and decent appearance, and should be adapted to the climate of the locality. The water supply, drainage, garbage disposal, and sewage facilities should attain at least the minimum standard known to all students of sanitary engineering. When tenants change, a house should be thoroughly cleaned and painted before a new occupant moves in.

The question of keeping domestic animals will sooner or later confront the management, and the best plan is to provide a single center for the quartering of cows, horses, and pigs, so that a standard of sanitation may be upheld and the spread of certain diseases prevented.

Much may indirectly be accomplished by teaching the school children of the community proper ideas of sanitation and hygiene. A capable visiting-nurse, serving as sanitary officer under the mine physician, will be able to effect many improvements in the hygiene of the community, through inspection of living arrangements and testing of water, milk, and food.

In the early stages of a mine's development, if the company is not able to put up a good hotel as a preliminary arrangement, it should not make the mistake of building a bunkhouse of the old-

fashioned sort, in which twenty or thirty men are crowded into a small building under conditions that make self-respect and contentment impossible. It is much better to build small two-room cabins, with accommodations in each room for two men. When the mine prospers it is easy to tear down such dwellings to make way for more permanent and comfortable quarters. Well-cooked and ample food furnishes a simple but important source of satisfaction, and the company mess-hall or boarding-house should not be run to obtain a profit; if in any one month a profit is made, the next month should be conspicuous by an enlarged bill of fare.

Underground sanitation and working conditions.—The dangers to health in the mine workings are very much greater than those existing at the surface, for the urgency of supply of necessities and disposal of wastes and drainage are ever present, and the difficulty of obtaining a healthful, invigorating, and dust-free underground atmosphere is one of the chief problems in mining practice.

The first requisite for working underground is a plentiful supply of potable, germ-free water. The workman should not be obliged to go more than a short distance from his work to obtain drinking-water: if the supply cannot be piped throughout the mine, fresh water should be daily transported to the working-places in kegs or tanks on mine cars. Such containers should be locked so that water may be obtained only from a spigot; if water is piped, the outlet should be a bubbling fountain or a pipe union too large for the drinker's mouth, or the outlet may be placed in a niche so that a cup must be used. A common drinking cup should never be permitted; contagious diseases such as typhoid, colds, influenza, and syphilis may be transmitted in this way.

No more deadly source of infection may be encountered underground than unremoved excreta; hookworm disease and dysentery are spread through this medium. Closed containers should be used, and emptied, cleaned, and disinfected as soon as possible.

Provision for drainage and air-conditioning are of prime importance in the design of mine workings (see Young's *Elements of Mining*, pp. 149–232). The effect of proper ventilation cannot be overemphasized. Air should contain not less than 19 per cent oxygen, nor more than 1.25 per cent carbon dioxide, and should be completely free from carbon monoxide or other poisonous gases.

It is well known that the output of workers in hot or humid mines is frequently less than half that of workers in well-ventilated mines where an air current keeps the underground atmosphere pure,

cool, and dry. If the temperature is above 75° F. and the humidity approaches saturation so that the body cannot obtain relief by sweating, there is a great impairment of physical ability and comfort, and, furthermore, the liability of accidents increases. Poor ventilation, even when the workers do not exert themselves greatly, causes such symptoms as lowering of blood pressure, rising of bodily temperature, increase of pulse rate, profuse perspiration, dizziness, exhaustion, and sometimes nausea, inability to think quickly, and headaches (which also result from failure of the ventilating system to remove thick air and powder smoke). Says Lanza:

> So remarkable are the benefits, so far as efficiency is concerned, where previously inadequate ventilation is remedied that further argument is unnecessary in its favor. An example of this came under my observation recently. The cost of driving a long drift, about 2,000 ft. below the surface, was $15 per ft., paying on a day-labor basis; the place was hot and moist; a small blower fan was installed at the shaft, with a canvas pipe leading nearly to the working face. Without any other changes the cost was reduced to $8 per ft. In shaft sinking this mine had made 50 ft. in one month and 60 ft. in another. A small blower with canvas pipe was installed and the next month a progress of 120 ft. was made. No better evidence could be given of the deleterious effect of poor ventilation on working ability.[8]

Increased drinking of water during a period of heavy physical exertion accompanied by sweating does not affect to any extent the consequent rise in bodily temperature and thickening of the blood; water drunk during sweating produces a greater excretion of water and minerals. These disturbances may be corrected by supplying workers with a one per cent saline solution for drinking at such times.

Siliceous dust causes a greater mortality than that resulting from all accidents. It is the irritant which causes silicosis, leading to fibrosis and tuberculosis, and any worker exposed to inhaling air containing these sharp particles should be protected by strong measures to combat the dust evil. Siliceous particles are not coughed up, but penetrate into the lung tissue and cause the diseased condition termed "silicosis," which has taken a heavy toll in such mines as those of the Rand and Western Australia. "Fibrosis," the first result of continued inhalation of silica dust, is the condition in which a growth of fibrous tissue replaces sound lung tissue, and this provides a fertile growing ground for the propagation of tubercular bacilli, resulting in tuberculosis, phthisis, or "miner's con." All

[8] Lanza, A. J., "Underground Mine Sanitation," *Engin. Min. Jour.*, Oct. 6, 1917.

workers handling quartz ore at any place in a mine or mill should be examined from time to time so that they may be removed from dust exposure if they develop symptoms of silicosis. Every safeguard should be taken to prevent inhalation of such dust particles: these include compulsory wet drilling, wetting of rock faces, sprinkling of working-places and ore heaps, strong ventilating currents, blasting at the end of a shift, and dust-proofing walls with the cement gun. According to Sayers, fine silica dust remains suspended in the air for hours, and is the most dangerous to breathe. An approved type of respirator should be worn by workers in exposed places, but since masks are usually uncomfortable and since silicosis takes several years to become acute and punishment is therefore not swift, it is hard to make the worker exercise proper precautions.

Dust from ordinary metallic ores, limestone, shale, and coal does not cause phthisis. On the contrary, coal dust (although providing an explosive mixture which may be ignited by an open flame) and other non-siliceous dusts have been proposed by Haldane[9] to counteract phthisis; such dusts cause the production of "dust cells" in the lungs, which are coughed up and thus the harmful particles are likewise eliminated. In support of this he calls attention to the non-production of silicosis in British coal mines which are rock-dusted to prevent coal-dust explosions, although the dust used for this purpose contains about 35 per cent quartz and nearly 60 per cent total silica. Countering dust with dust may well prove a solution to the evil, and in some of the Rand mines, workers exposed to silica dust are transferred to work in the coal mines of Natal for a month each year.

Disorders and diseases encountered in the mining industry.— There are a number of afflictions, other than phthisis, to which workers in the mining industry are exposed. Some of these are of such great virulence that they make the conduct of mining operations in certain districts of the world almost impossible. Malarial conditions even under extreme sanitary precautions may render half the members of a staff incapable of performing their work with any efficiency. Or cholera may pounce over night and force a shutdown for months while the native laborers lie stricken and terrorized and the surviving white men devote all their energies to the burning of

[9] Haldane, J. S., "The Avoidance of Silicosis with Dry Methods of Working," a paper presented before the Joint Meeting of Sections G and I, British Association, Johannesburg, 1929.

bodies. Healthfulness of climate forms one of the chief considerations in the valuation of a mine and the planning of operations. Young engineers about to take a position in a part of the world that is subject to more than ordinary health hazards should take a physical examination in order to make sure they are fit, and should furthermore obtain all reliable information that they can concerning diseases that may be encountered and the best means of guarding against and treating these diseases.

Malarial parasites are injected into the body by the bite of the female mosquito of the genus *Anopheles,* "the mosquito that stands on her head." That the prevalence of malaria, even in the tropics, can be greatly reduced by combating the mosquito has been shown by the work of the Americans in the Canal Zone, and in many mining districts throughout the world. The insects swarm just before dark and are capable of traveling more than a mile. The first step in fighting the mosquito is to install a drainage system that prevents the accumulation of even the smallest pools of stagnant water, in which the larvae breed. Such neglected breeding-places as discarded sardine cans and tobacco boxes should be discovered and eliminated. A common and often forgotten breeding-place in the tropics is the sheathlike receptacle at the base of the banana plant; each plant has from three to six of these, each receptacle holding anywhere from a quart to a gallon of water, and, as they cannot be drained, the plants within a mile of the living quarters should be cut down. Other foliage in the neighborhood should be removed. Sluggish streams can in many cases be stocked with goldfish, carp, stickleback, or small minnows, which will shortly do away with the larvae. The next precaution is to house all white employees in screened dwellings and offices that will not permit the entrance of the small and persistent mosquito; dwellings should, if possible, be on high ground. The recognized preventive and treatment agent is quinine. As a preventive, three grains of quinine should be taken before each meal, and constipation should be avoided. The symptoms and treatment of malaria should be known to all mining engineers:

Symptoms: fever or chill, sometimes accompanied by violent vomiting; in former case, induce active perspiration with hot lemonade, acetanilid or other antipyretic; in latter case, empty stomach with 30 grains ipecac and much tepid water, followed by 5 grains soda bicarbonate. *Treatment:* 15 to 20 grains of quinine 3 times a day; more quinine than sufficient to induce dizziness is not necessary. Promote movement of bowels by 10 grains calomel mixed with equal weight sodium bicarbonate, taking 0.25 of mixture every 20 minutes. Six hours after calomel, take 1 ounce magnesium

citrate in water, followed 2 hours later by 20 grains quinine. Patient should remain in bed at least one week, taking 30 to 35 grains quinine per day, in 2 or 3 instalments, and continued until 25 days pass without return of fever.[10]

The sufferer usually has sufficient warning to escape to a healthier climate, and should be sent to a sanitarium for treatment; he is not, of course, immune to another attack immediately if he returns to the old conditions. If a man on a mine staff will not take every precaution to prevent malaria and other infectious diseases, he is just as incompetent to hold his position as if he were deficient in technical or administrative ability.

Yellow fever is another mosquito-borne disease, carried by *Stegomyia fasciata,* and promoted by high temperatures, low barometric pressure, lack of cleanliness, and impure water. It is particularly likely to attack newcomers, and recovery from the first stage, lasting from two to six days, usually brings immunity. Quarantine, disinfection, complete rest, and liquid food are indicated.

Cholera, an epidemic disease, is caused by a bacillus entering the body with food or drink and lodging in the intestines. The onset is sudden, and is accompanied by painful abdominal gripings, severe diarrhoea, and complete collapse. Although the duration of the disease may be as short as two hours, in fatal cases death usually ensues on the second or third day. In the first stages, the disease should be treated by enemas of opium and tannin, with stimulants, and by bathing the patient several times daily with disinfectant solution; diet should be thin porridge exclusively. Isolation, extreme cleanliness, and moderation in food and stimulants are necessary.

Other health precautions to take in a tropical climate include boiling of doubtful water, a light and varied diet (fresh fruit and vegetables should be washed, peeled, or cooked), and few or no stimulants, avoidance of exertion, taking siestas in the middle of the day, protection of head and back of neck from direct sunlight, wearing of light clothing, frequent changes in order to prevent clothing from drying on the body, and specific preventive measures such as taking quinine in a malarial district.

Ankylostomiasis or hookworm disease exists in many parts of the world, and has been prevalent in mines in Africa, Italy, Germany, Belgium, Cornwall, and the southern United States; in many California quartz mines a majority of the workers are mildly affected.

[10] Peele, Robert (ed.), *Mining Engineers' Handbook,* 2d ed., pp. 1551–52.

The disease is caused by a small blood-sucking worm attaching itself to the walls of the intestines, after making its way, in larval form, into the body by boring through the skin or by entering with infected food. The larvae may live in suitable soil for nearly a year, and hence infected ground is a reservoir for spreading the disease. The disease is detected by microscopic examination of dejecta for hookworm eggs; symptoms of advance cases include stomach pains, starved and bloodless appearance of skin, capricious appetite, and, especially among children, bloating of face, abdomen, or legs. The disease is easily and quickly curable by a physician using vermifuges; but if it is not treated the worms may live in the body for ten or fifteen years, even if there is no reinfection. The company doctor should make frequent examinations to discover whether persons or soil are infected, and all new workers should also be examined. Preventive efforts include the wearing of shoes without cracks or holes, wearing leather gloves, and rigid sanitary precautions such as washing hands before meals, frequent removal of wastes and disinfection of underground latrines, and pure drinking-water.

Pneumonia may result from exposure to the great changes in temperature to which miners are frequently subjected. The best preventive is a well-built and warm change house where workers can bathe and change their clothing before and after a shift. The change house should be close to the head of the shaft, and an inclosed passage should lead to it to protect miners coming from work from taking a chill.

"Soroche" or mountain-sickness attacks some newcomers in high altitudes, and causes headaches, nausea, vomiting, and nosebleed. If the symptoms do not soon pass off, there is nothing to be done but remove to a lower altitude.

"Verrugas" is an endemic disease peculiar to Peru, and caused by a special bacillus. It is characterized by warty surface tumors which ulcerate and bleed, and is frequently fatal.

Cyanide poisoning may result from taking cyanide solution internally or from inhaling hydrogen cyanide gas; the effects of the latter are almost instantaneous. Death is caused by asphyxia; symptoms are disturbance of vision, vertigo, attacks of suffocation, contraction of muscles, blue lips and fingernails, dilated pupils, convulsions and sometimes frothing at the mouth. If the poisoning is not severe, artificial respiration, administration of oxygen, and a hypodermic injection of stimulants, and, if the poison has been swallowed, a quick emetic, are efficacious. An effective treatment

for cyanic poisoning as well as other types of severe asphyxiation has recently been successfully used. It consists of an injection of a one per cent aqueous solution of methylene blue, a common dye. Administered shortly after the poison has been taken, this treatment has quickly revived a patient who drank about fifteen grains of potassium cyanide. The fumes of cyanide are a constant danger in a treatment plant; ventilation should be good at all times, and workmen should not enter empty tanks in which cyanide solution has lain, as decomposition will frequently give off enough gas to cause poisoning. Death by fumes has been caused through accidentally spilling acid on the floor of a cyanide plant; generation of deadly gas in such a case is instantaneous.

Workers handling mercury should take precautions against poisoning by covering the skin and by avoiding the swallowing of ore dust or the inhalation of vapors. The most prominent symptom is salivation. If mercurial salts have been swallowed, egg-whites or emetics should be promptly administered.

Poisonous metallic dusts, such as lead, cinnabar, or arsenical ores, should be guarded against by protection from inhalation of dust and by washing of hands and face when coming off shift. Particles of poisonous dust may be taken into the mouth with food.

WELFARE ACTIVITIES

Certain welfare activities may be undertaken by the company in an effort to make their employees comfortable and contented and to further the social and recreational life of the community.

Old-age pensions, compulsory savings plans, and group insurance are measures instituted by many companies to lower labor turnover and encourage the habit of saving.

If the company operates a store for employees, the prices charged should be as moderate as possible and the service good, since the main purpose of such a store is not to make a profit but to provide employees with as high a standard of living as possible and to create satisfaction.

Many recreational activities may be assumed by a club formed among the employees. In order to avoid an objectionable paternalism it is better for the company to encourage employees to take the lead in the formation and administration of recreation and social activities, itself supporting rather than promoting such plans. If the town is of sufficient size, a clubhouse may be built to contain a lounging-

room, a library where books and magazines are available, a dance floor, tennis courts, and even a swimming-pool.

In many mining towns the moving-picture theater has become almost essential. Some companies operate free picture-houses, giving out tickets in rotation to all workers and their families; free showings permit a proper selection of films to be exhibited. As an attraction for labor, this feature of free community entertainment has no superior. It may also be effectively used as an educator; there are available many industrial and safety-first films which may be of real value in showing proper methods of work and inspiring good habits of living. The operation of a picture-theater need not be a great expense; one man can ordinarily handle all the details of the business.

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Chapter 27

The Young Engineer and His Career

Mining and metallurgical engineering is a professional calling, and the members of this profession apply for the benefit of mankind the store of scientific knowledge that they have mastered. A profession differs from a trade or craft in two ways. First, it presumes that those who practice it will do more than merely perform certain mechanical functions, that they will bring to the task set for themselves a body of scientific knowledge and an inventive skill in applying it, and will, moreover, have some executive ability, business experience, financial insight, and the engineering sense described by Herbert Hoover as "that fine blend of honesty, ingenuity, and intuition which is a mental endowment apart from knowledge and experience." Second, the profession demands that its members recognize certain definite obligations—to their colleagues, to their clients, and to the public at large—which may, on many occasions, transcend their personal interest.

Although mining and metallurgical engineering is not a business, its commercial aspects are more prominent than are those of any other main division of engineering; and any volume concerned with the economics of mining would be incomplete were it to neglect the important topic of the mining and metallurgical engineer as a business man. Aside from dealing with this subject, this concluding chapter will also discuss the aptitudes and training required for success in this branch of engineering; the opportunities for making a career in various fields of endeavor, at home and abroad; customary professional practices considered to be ethical and just; and the rewards of a successful devotion to an old and honorable vocation upon which rests the future of civilization.

REQUIREMENTS FOR SUCCESS

In addition to the personal characteristics that are requisite for success in any profession, the mining and metallurgical engineer

should possess a rugged physique and perfect health, a broad general education and special instruction in the fundamental principles of mining and ore-treatment techniques, the engineering habit of mind and rigid mental honesty in applying the engineering method to problems in the mineral industry, practical experience in the field, a well-developed financial sense, an intense dislike for slovenliness and disorder, and a recognition of high obligations to his profession and to society.

Physique.—Although a strong constitution and perfect health are virtually an essential for work so physically exacting as that of the mining engineer, it is quite conceivable that a man of indifferent constitution but possessed of fairly good health could specialize in secretarial, administrative, or research work which would keep him in a metropolitan area throughout his career. He might in this manner eventually win to high distinction in his profession, but he would labor under the handicap of lacking actual contact and experience with practical conditions in those far, raw places where metals are won from the earth.

Aptitude.—The aptitudes and interests that will incline a young man to embark in this career are in general those that would lead him into any other field of engineering: a liking for accomplishing things by the use of machinery and for manipulating tools and operating machines; an inclination toward science and mathematics; a ready invention in the design and application of useful devices; and an orderly and logical habit of mind and persistence in applying the engineering method to the solution of problems both technical and human. The prospective mining and metallurgical engineer should also consider whether or not he is capable of developing, to a high degree, facility in handling financial concepts, in dealing with men, and in assuming leadership in the attempt to inspire an organization loyally and efficiently to attain a high goal of achievement.

Training.—The inherent capacities of the young aspirant should be developed and supplemented by a good university education and by practical experience in his field. In these times completion of a four-year course in a college or university is a minimum essential to success; and this course should be extended, if it is at all possible, by two years of graduate work. The university can contribute by giving a training which exercises, invigorates, and disciplines the intellect and at the same time develops and strengthens the character. The course in mining and metallurgical engineering should deal

mainly with principles, not details of practice. The trend of engineering education has of recent years been too strongly specialized. Mining schools have devoted entirely too much time to the so-called practical courses; these courses are on the contrary extremely impractical, for methods change rapidly and, moreover, too close application to details of technique is likely to obscure the broader general concepts that should form the background of a liberal engineering education. An engineer's curriculum should consist of at least six years of training in English, languages, history, economics, and pure science, along with sufficient specialization to familiarize him with the fundamental principles of his profession. Methods, processes, apparatus, and machinery change from generation to generation, but the fundamental principles of mining, concentrating, amalgamating, and smelting are always the same. The young engineer, then, should be given a broad cultural background, scientific habits, and an elasticity of mind developed through practice in a wide variety of problems; this training should so condition his attitude and outlook that a year or two of contact with his profession will readily enable him to comprehend the details of methods and processes he will encounter in the field.

PATHWAYS TO SUCCESS

The work of a mining and metallurgical engineer, as has been suggested in the preceding pages, covers such a broad range that most of his functions can merely be mentioned and only a few examples can be given of the pathways by which successful members of the profession have attained distinction.

Nature of the work.[1]—The work of a mining engineer covers so broad a field that no more than the briefest outline of his activities can be given. He may enter his profession by a number of doors, these being generally the lower positions of an elaborate mine staff. This staff is usually organized in the old line formation, each step of which is in the nature of a promotion, giving added responsibilities and remuneration. Nearly all of the individuals of this organization may be correctly described as mining engineers if they have had the necessary educational preparation. A man may fill the position of assayer for years and may yet be potentially or actually

[1] This paragraph is extracted from "Vocational Information," *Stanford University Bulletin,* Oct. 1, 1923. It was written by the author of this book.

a mining or metallurgical engineer. A mining engineer may be called upon at some stage of his career to do assaying, chemical and metallurgical analyses, sampling, surveying, map-making; to work out the geologic and petrographic structure of ore deposits; to work perhaps as a laborer or miner; to act as chief boss or foreman in the mine, mill, smelter, or other works; to estimate values of deposits, act as weigher; to perform secretarial duties to manager or other superior officer; to superintend the departments of mine, mill, smeltery, power plant, railroad, forests, sanitation, or mechanics; or to administer and manage the whole economic development and operation of a mining or metallurgical project. The mining engineer may not only be called upon to perform all the above duties, but he may even secure, organize, and manage the capital with which the project is made possible. The whole trend of modern industry is in the direction that the engineer may, and often does, fill the position of president or chairman of the company; he may be a director or serve as managing director and act as consulting engineer or be on the technical committee, with or without a seat on the board of directors. It will be observed that these last-mentioned officers must of necessity be at the place where the main office is located, and not at the mine. A man filling these higher functions will probably fill similar positions for a number of companies. He will make periodical journeys of inspection to the respective properties, which generally lie at a long distance, or in foreign countries. The working conditions under which the mining engineer operates range therefore from those of the metropolitan districts of New York, London, San Francisco, etc., through all grades of comfort and discomfort to the desert and the jungle.

Functions of the engineer.—From the previous description it is apparent that the work of the mining and metallurgical engineer falls roughly into the divisions of mining, metallurgy, geology, administration, and finance. He may, in these various divisions, perform any or all of the functions of research, invention, valuation, management, organization, promotion, design, construction, operation, production, maintenance, safety work, testing and inspecting, selling, and distribution. Certain other special functions are open to his effort, as will be revealed by an examination of the steps in promotion attained by certain university graduates that are listed in the next section. These special fields of endeavor include teaching, technical writing and editing, government service, consulting, purchasing, prospecting, sales promotion, legal work, and the like.

Line of promotion.[2]—The profession of mining or metallurgical engineer has several avenues of approach. The young engineer upon leaving the university generally takes the first situation available. This will come as a direct offer from the manager of a mine. The position is usually a subordinate one but one which an intelligent graduate can fill with a fair degree of success after a few weeks' coaching by his predecessor or some higher staff officer. These subordinate positions which serve as avenues of approach to the higher and more remunerative positions in the profession are in the main as follows: assayer, chemist, metallurgist, geologist, surveyor, miner, millman, bookkeeper, storekeeper, timekeeper, record-keeper, weigher, secretary, and sampler.

The following paragraphs indicate the line of promotion of a number of mining engineers, university graduates whose careers are familiar to the author. The first position held on leaving the university is given first, and then the successive steps in the line of promotion. These promotions may not always come in the employ of one company, and occasionally a man takes a position which is a step backward, but not often.

1. Mill foreman, assayer, assistant editor of a mining publication, superintendent, consulting metallurgist, superintendent of smeltery, editor of mining publication.
2. Railway construction, surveyor, mine foreman, manager.
3. Assistant on exploring expedition, assayer, mill foreman, assistant manager, government mining adviser.
4. Assayer and analyst, chief chemist, metallurgist, general manager, consulting engineer.
5. Chemist and electro-metallurgist, assistant metallurgist, metallurgical engineer, manager.
6. Assayer, assistant superintendent, superintendent, consulting engineer, manager, director, managing director, chairman, president, independent consulting engineer, professor of mining.
7. Draftsman, surveyor, prospector, geologist, superintendent, manager, consulting geologist.
8. Surveyor, assayer, mill foreman, smelter foreman, professor of mining.
9. Shoveler, surveyor, estimator of ore reserves, superintendent, geologist.

[2] This and the following section of the present chapter are extracted from "Vocational Information," *Stanford University Bulletin,* Oct. 1, 1923. They were written by the author of this book.

10. Laborer, surveyor, timekeeper, store manager, examination and exploration work, engineer and resident manager.

11. Surveyor, mine shift boss, foreman, superintendent, manager, general manager.

12. Laborer, prospector, surveyor, clerk, paymaster, cashier, superintendent.

13. Helper, miner, timberman, assayer, superintendent, manager, consulting engineer, managing director, president.

14. Storekeeper, sampler, surveyor, assistant superintendent, manager.

Income and rewards.—The income and rewards in this profession are liberal. At the bottom the remuneration is equal, if not superior, to an ordinary trade, and it increases rapidly with each step in promotion until it reaches, in positions of trust, \$4,000 to \$20,000 per year. As much as \$50,000 has been paid for an examination and report on a single mining project. The sum of \$10,000 per year has been paid as salary to consulting engineer, managing director, or president of a mining or metallurgical company. Fees for independent consulting work have frequently amounted in individual cases to as high as \$100,000 per year. While speaking of the rewards of the profession, the disadvantages and discomforts should be pointed out. The worst of these is long-time residence in foreign and semicivilized countries. This residence abroad may either leave a man out of contact with his own country until he loses interest therein, or it may lead directly to sidetracking him in his profession; or residence in tropical countries may destroy his health or kill him.

Getting established.—Most colleges and technical schools nowadays make every effort to keep in touch with industry in order to help place their graduates in promising positions. But the student cannot expect that at graduation, or at any other time, he will be presented with a good job; it is his responsibility to discover an opening and make his merits known to a prospective employer. One of the best ways in which to assure that a position will be open after graduation is to devote summer vacations from college to working at some mine or plant, thus enabling the employer to judge the student's abilities through close contact on the job.

Although the first position won after graduation is likely to be highly important in determining the future course of activity in the profession, and the various factors of the situation should be weighed with unusual care, it is seldom that the newly made engineer

will be able to pick and choose from a multitude of promising offers. He should not scorn to take any honest work, no matter how lowly, that holds forth prospects of advancement to a higher post which he feels will offer a scope for his talents and ideals. Although a large organization can sometimes give a young man better working facilities and greater security of tenure, it may happen that his initiative will be stifled and that he would learn more and win to responsibility sooner on the staff of a small mine under the guidance of an understanding superior officer. Youth is the time for pioneering, for tackling the difficult task and winning through against odds. If the way to advancement is open and the young man is put on his mettle, the challenge will not be refused.

ETHICS AND PROFESSIONAL CUSTOMS

Mining and metallurgical engineers have never subscribed to any formal code of ethics similar to those that have been adopted by professional societies in other fields.[3] The spirit that prompts the regulation of professional conduct is doubtless excellent, but many sections of these codes give the impression that engineers are ignorant of the fundamental principles of fair dealing practiced by every honest man. Most members of the profession have always observed the spirit of such codes, forgetting the letter. The transgressor is seldom one who acts in innocent ignorance, but rather the shyster and the crook, who are deliberately dishonest and who will continue to disregard any moral code that does not provide any means of enforcing its provisions. Moreover, when the professional code becomes explicit, it enters debatable ground where actions can be judged not upon the basis of precise commandments but only upon personal good faith and honorable intention. Many of these codes, even when drawn up by a body of able engineers, are extremely imperfect of application and are perhaps worse than no code at all. If an engineer consistently engages in practices that he would be ashamed to acknowledge before the world, he needs no printed code of ethics to tell him that he is lacking in self-respect, professional honor, and that personal integrity upon which depends the mutual confidence necessary to success in all dealings between man and man.

There are, however, certain professional practices which have

[3] See "Ethical Standards Proposed for Engineers," *Engin. Min. Jour.*, June 9, 1923, p. 1029, which gives a code of fifty articles prepared by the National Practice Committee of the American Association of Engineers.

been recognized by long custom to be fair and just. Many of these have already been discussed, in connection with mine valuation, sales promotion, finance, and industrial relations. It will be well here, nevertheless, to summarize, for the guidance of the young and inexperienced mining and metallurgical engineer, the obligations which he owes to his profession, to his brother engineers, to his employer or client, to society, and, finally, to himself and his career.

Obligations to profession.—The young engineer should regard himself as a debtor to his profession and to the generations of those who have gone before him and created the store of technical knowledge upon which he draws. He should devote himself to the advancement of this knowledge, and should at all times give consideration to the good name and dignity of the profession he has adopted as his life work. Before definitely associating himself with the practice of mining and metallurgical engineering, he should make a candid appraisal of his qualifications and ask himself whether or not he sincerely believes that he has the aptitude, ability, character, and perseverance requisite to an honorable and successful career in this field. If he holds any grave doubts that this branch of engineering offers for him the most satisfying field for a lifetime of endeavor, he should not risk the humiliation of failure and false starts, but should at once search elsewhere for his true vocation. No man can be happy or whole-hearted in his work if he is forever looking backward, wondering if he has taken a wrong turning, and repining.

Obligations to brother engineers.—All engineers should freely share their professional knowledge and experience with other engineers on all occasions when this involves no breach of confidence. The young engineer should join one or more professional societies and take an active part in their discussions. Although in some special cases, when engineers are employed by rival companies in the same area, it is sometimes difficult to indulge in the pleasant and profitable custom of "talking shop" for fear of divulging business information, the usual friendly relations and honorable dealings should prevail. Fidelity to employers who are business rivals may require that engineers become partisans, but it never need be the occasion of engendering personal animosity.

The engineer should not attempt to advance his own interest at the expense of any other member of the profession, to injure the reputation or prospects of another in any way, or to take unfair advantage in securing employment; nor should he criticize the

work of other engineers unless he has been regularly engaged to do so.

An engineer should never perform professional services gratuitously; even though he is so affluent that he does not need the fees for such services, he should not stand in the way of someone else who must earn a living. Of course, compensation may frequently be so intangible that it would be difficult to place a monetary value on it or to prove that the service was not rendered gratuitously; but in every case there should be some valid and valuable consideration accepted. The opportunity to gain useful experience may be counted as a valuable consideration, but this idea may be carried too far; an engineer should not give this consideration such a high valuation that competing engineers are incapable of bidding against his offer.

All relations between engineers should be conducted with full regard for the dignity of the profession. Litigation between engineers should be avoided by every honorable means; there would seem to be no occasion for any controversy that cannot be settled by amicable discussion or, at worst, by submission of the various contentions to a committee of engineers made familiar with the facts.

It is an act of common justice for a man to give full credit to all colleagues or subordinates who contribute to the success of an undertaking. Furthermore, it is the duty of an older and more experienced engineer to go out of his way to assist in the professional development and advancement of the generations that come after him. Such sympathetic interest and appreciation will ordinarily call forth, from the subordinate, loyalty that should be free and unswerving. In extremely rare cases, the subordinate may perceive that the actions of his superior officer are at odds with the best interests of the company by whom they are both employed, and it may be difficult for him to discover to which of these parties his loyalty is due. If there is an honest difference of opinion that cannot be reconciled, it may be necessary for him to go to the length of writing out a statement of his point of view and sending it, preferably with the full knowledge of his superior, to the managing head of the company. Of course, if the young engineer has any well-founded suspicion that he is engaged in activities which are being carried on for unsavory or fraudulent ends, there is no other path for an honest man but that of immediate resignation.

Obligations to employer.—Perhaps the greatest cause of discussion concerning professional practices centers about the relations between the engineer and his employer or client. This is necessarily

so, because the arrangements under which an engineer performs professional services are many and various and the amount and mode of compensation for these services are conditioned by a number of complex factors. Aside from the legal relationships of the two parties described in chapter 19 during the discussion of contracts and the law of agency, there are a number of mutual obligations between engineer and client which have not been and can never be reduced to dogmatic rules. Among these may be mentioned: fees, provision for expenses incurred during service, supplying of equipment, consultation and other extra expenses, ownership of original documents, right to publish information obtained during period of service, progress reports, the responsibility of the engineer to state his conclusions with as much finality as possible, and the ethics of buying shares in an enterprise with which the engineer is connected.

The engineer will ordinarily accept payment for any work from one source only, and will inform his client or employer of any business interests which might tend to impair his judgment in any way.

If the time required for the work to be undertaken by the engineer can be closely estimated, it is better to charge a fee than to serve on a salary basis; but if the engagement is to hold for some time, or if the work, for example, is a mine valuation in a distant country and neither the traveling time nor the time required for examination can be definitely stated, it is better to request a salary. If the client is known to be reputable, it is not always necessary to sign a formal contract for the work; an exchange of letters or telegrams is usually sufficient in such a case, although the arrangements should, for the protection of both parties, be made as clear and definite as possible. Frequently clients are willing to advance a lump sum to cover the fee and estimated expenses of the trip, and if this is not offered voluntarily the engineer would be right in requesting a retainer of at least half the amount in advance. An ideal plan would be to have the client deposit the full amount in the bank under an escrow arrangement, whereby the sum would be handed over to the engineer on receipt of his full report; but many business men are sensitive when their credit is in question and might resent such a proposal. Ordinarily it is not difficult to get a guaranty from two or more persons to pay the account. The agreement should, of course, always be in writing.

Engineers should avoid overestimating or underestimating the value of their services; a client's ability to pay cannot justify an excessive charge, although in some cases, if he is unable to defray

all the expense, some other consideration may be accepted if there are strong reasons for doing so. As the rates of payment for all engineering services vary with the years, it is impossible to state any typical amounts for different kinds of work. Discussion among experienced engineers will ordinarily reveal suitable rates to be charged for certain work at a given time and place. Some of the factors which should be considered when determining a proper fee are: time and effort required; the novelty and difficulty of the problems involved; physical risks and discomfort; possibility that employment will lead to further important engagements, or that it will on the contrary bar the way to other profitable connections in the future; the amount of money involved in the results of the engagement; the certainty of payment for services; and, finally, the customary charges made by other engineers for similar work.

It is logical to charge the employer with all expenditures which might reasonably be made in his behalf, and many engineers are further inclined to consider as proper items on an expense account all those personal expenses that an individual would incur had he been traveling on his own business. The best way to deal with this question is to request that the employer make a per diem allowance based on the cost of living in the territory in which the engineer is to travel; this cost can be closely estimated for most countries. This obviates debate concerning the propriety of including certain personal items, and also does away with the nuisance of trying to keep a detailed daily account of disbursements, often in two or three different currencies.

Engineers are entitled to first-class accommodations when they travel, and should maintain themselves on a scale that will not reflect adversely upon the dignity of their profession. Tips are expected in most countries, and a moderate amount for this item is a legitimate charge on the expense account. The custom of billing employers for amounts spent for entertainment is one which may readily lead to abuse, although there are some instances in which an engineer may properly pay out his employer's money in an effort to attain goodwill. Ammunition for sport during an expedition is obviously a luxury, but ammunition for the purpose of securing meat in the wilderness, or for protection in a wild country, is a proper expense. Tobacco is considered by most engineers to be a necessity, and as such may also legitimately appear. Medicines are, of course, a prime necessity, although the average engineer usually carries with him his own kit. However, custom does not justify charging the em-

ployer for large medical expenses for injuries incurred during service or diseases contracted in unhealthy areas. Engineers should therefore not undertake employment in foreign countries without having a definite understanding concerning such disability; many mining companies undertake to protect their employees through some form of insurance.

An engineer is expected to provide his own personal outfit and the ordinary tools of his profession, such as surveying instruments, drawing and writing materials, assaying kits, and the like; but the employer may properly be charged for any special equipment required to make a complete examination or to perform the necessary services.

Special large expenditures, not contemplated at the time the employment agreement was made, should not be undertaken without obtaining the employer's consent. Such expenditures might arise during the valuation of an old mine, which upon inspection is found to be badly caved or partly watered and requires for proper examination an unforeseen outlay for unwatering or clearing the drifts. Again, it sometimes happens that an engineer discovers that he is not suitably equipped to give judgment upon certain parts of his work. In such a case, instead of taking the risk of neglecting important considerations, he should frankly inform his employer that he considers it essential that a consultant, with an expert knowledge of the special point of technique in question, should be called in. Engineers in such a situation have sometimes, without authority, secured such expert advice and even advanced a fee for these services. The risk of such a course is grave; one result of pretending to knowledge which the engineer does not in actuality possess is, obviously, that there may come a time when his ignorance is displayed under questioning, and the imputation of trying to cover up a deficiency is hard to belie.

The question of ownership of original records, such as field notes, letters, and other documents compiled by the engineer, is not fully established by precedent, and it is wise to have an understanding on this point at the time the engineer is engaged. Although it is customary among civil engineers making surveys to consider their field notes as an integral part of the survey and therefore the property of the employer, most mining engineers dissent from this opinion; they consider that their notebooks more nearly correspond to the case-book of a physician, which no one would suggest should belong to the patient. The mining engineer's original notes record his accumulated experience, which is a part of his stock in trade,

and if for no other reason than to protect himself and the public against misrepresentation, they should not pass out of his hands. In his report (which, of course, is solely the property of the client) the engineer will give all the salient original data, and will also file complete copies of all his calculations so that they may be checked by other engineers. If the employer desires a record of the original notes, it is easy to give him photostatic copies of them.

The engineer should retain copies of all correspondence and other documents to which he puts his name. Many English mining companies take exception to this and unreasonably maintain that all letters written by anyone while in their employ are an integral part of their business and that not even copies of such communications may be kept by the writer. Here again the right of an engineer to keep copies of all documents bearing upon his acts or reputation should be upheld as a measure of protection to himself and the public. Copies of many related documents, which are not addressed personally to the engineer but which are necessary to elucidate documents which do contain his signature, should also be kept.

A mine report belongs, of course, to the client who pays for it, and the engineer is not free to divulge or publish any facts which he has acquired during the course of an examination unless the client gives his permission. This permission is much more easily secured before the report is made; usually the engineer can obtain the privilege of publishing in the technical press any matters of professional interest which do not infringe upon or complicate the financial arrangements of the client—but the latter is the best judge of what points should be kept secret. The engineer is ordinarily released from maintaining silence upon the results of a mine examination when the option to purchase has been allowed to lapse, when other engineers have also reported on the property, or when developments at the mine have advanced to such a point that the early examination has become ancient history. Before offering the results of a mine valuation elsewhere, he should if possible obtain a written statement from his former client, stating that the client is no longer interested.

Progress reports on the results of a mine examination should never be promised by an engineer. Until he has completed his inspection, any comments he might be able to make on the possibilities of the property would be worthless, if not actually misleading. If any periodic reports are made to the client, they should be confined to such topics as territory covered, expenditures made, and the current status of the work.

Engineers are often faced with questions for which a categorical yes-or-no answer is desired. They should not try to evade the responsibility of making direct statements within their province—that is what the engineer is paid for. True, it often happens that sufficient data do not exist to warrant any simple, conclusive judgment; but this fact should not be used as an excuse for dodging the consequences of a forthright statement of opinion on technical matters which the engineer is presumed to be qualified to judge. For example, it would be almost as unfair to the client to allow a large margin of safety and understate the estimated value of a property as it would be to indulge in unduly optimistic prophecies; engineers who "play safe" in this way are guilty of concealing pertinent facts which they have been paid to bring forth.

The engineer should not take advantage of his presence in a district, while serving a client, to examine and perhaps take options on mining properties on his own account unless this action has the express approval of his employer.

It is decidedly unethical for an engineer to buy shares in a promising property before his report has been made available to the shareholders and the public. The company employing an engineer is entitled to all the benefit resulting from knowledge acquired by the engineer at its expense; and he has no right whatever to try to reap a profit by virtue of using information that his employers do not possess. This does not mean, of course, that because an engineer has once reported favorably upon a property he should forever be barred from purchasing shares in the company, in amounts within the limit of his means; but rather that he cannot buy shares until after the report is in the hands of his client.

No one will deny that business confidences or trade secrets with which an engineer may become familiar during a period of service should be held inviolate. Difficulties may, however, arise when a business connection is dissolved, and it is sometimes hard to state what part of the engineer's knowledge and professional experience belongs to his former employer and what is his own personal possession. The courts will ordinarily hold that no employer can enjoin perpetual silence, or perpetual service, unless valid consideration, such as a salary, is concurrently given. Such dilemmas do not ordinarily come to a young engineer, and if the older engineer has not formed definite opinions on this point he may obtain valuable advice on the subject through discussion with his brother engineers. The most extreme case of this nature would be acceptance by the

engineer of a position with a business rival of his former employer. Doubtless such a situation could be carried out ethically and honestly, and without danger to the engineer's reputation; but the best advice that can be offered in such a case is: Do not attempt to work for an employer who is competing with a former employer if you can make a living in some other position.

Young engineers should beware of tying up their futures by signing long-term contracts. Many employment contracts are heavily loaded in favor of the employer, and a young man in the glow of excitement that comes to one embarking on a new adventure may easily be led to agree to provisions which he will later perceive are very much to his disadvantage. He should avoid such mishaps by obtaining competent advice on the possible consequences of the terms of any agreement he is asked to sign.

Obligations to the public.—The engineer should place his obligations to society before any other interests, and should endeavor to advance in the minds of the public the esteem in which his profession should be held. It is the mining and metallurgical engineer's duty to discourage gambling in fictitious values, to protect the investor against fraud and dishonesty in any form, and to do everything to diminish the wastes incident to providing the huge and steady supply of metals and mineral products upon which modern industry depends.

It goes without saying that he should not associate himself with any enterprise which is at all questionable or inimical to the public welfare. If an engineer becomes convinced that any work upon which he is engaged is visionary or fraudulent, he will of course immediately sever his connection and take steps to prevent the victimization of the public. Resignation in such a situation will also involve the return of all salary and fees paid him by an unscrupulous employer, so that he may with clean hands take steps to expose the business; this may work a temporary hardship, but after all, whatever the sum, it is a small price to pay for having made such a blunder, a small price for that personal integrity and professional independence which leave him free to take up the cudgels for honesty and justice. The engineer should, of course, have in his hands unassailable evidence of illegality before making any accusation, or he will lay himself open to an action for libel. However, a resignation may be made in such a manner that it will in itself constitute a strong criticism of the reputability of the venture.

The engineer should guard against misuse by others of a report which he has made; if a report is to be published, in full or in part,

he should require that proofs be submitted to him before publication. He will then be in a position to see that he has been correctly quoted and that fragments of his report are not put together in such a way as to convey a false impression, and to guard against the not uncommon "printer's error" alibi. If his name has been misused by the promoters of an enterprise, the columns of the technical journals are open to him for protest. Precision of statement in reports is a duty to oneself, the employer, and the public; no statements which are ambiguous, questionable, or couched in misleading terms should be published, for the public tends to accept the interpretation most favorable to its hopes of sudden wealth.

Reporting on a property in which the engineer holds a financial interest, a practice for which some men have been criticized, is not reprehensible if the connection is publicly avowed. Indeed, it is conceivable that an engineer might honorably perform professional services for a company in which he is also a director and an official, provided that all his financial interests in the enterprise are stated early in the report or prospectus. The report would hold greater weight, however, if it were rendered by an engineer whose judgment was free from any financial interests in the property.

Engineers are often called upon to testify upon technical matters in a court of law. They should remember, in such a situation, that justice and the public welfare are paramount; although they may be retained by one or the other party, they are actually "friends of the court" and are expected to state the truth as they see it. The spectacle of two equally eminent, experienced, and qualified engineers expressing in court diametrically opposed views on points of geology, physics, chemistry, or metallurgy may not be edifying, but there is nothing censurable about it if, before accepting any fee or binding himself as a witness, the engineer has made a thorough study of the question involved and is honestly convinced that his client is in the right. It is impossible to conceive that any engineer's need could be so pressing that he could bear witness in court to theories in which he did not conscientiously believe.

The engineer's duty to his native land requires that he live as a good citizen, hold himself ready to serve the public welfare at all times, and take an active part in promoting honest and efficient government. Many social obligations of the engineer as financier, manager, and mediator have been mentioned in earlier chapters.

Obligations to himself.—"To thine own self be true," counseled Polonius. The engineer owes it to himself to make his career a

satisfying endeavor that will demand the highest development of his powers and bring him to a position of dignity, honor, and consequence among those who direct the work of the world. His greatest asset is self-respect. He should study how to apply the principles of efficiency to his daily tasks and the engineering method of reasoning to all his thinking. His education will not end on the day he is presented with a university degree; it is his constant concern to prepare himself for greater and greater responsibility. During the periods of enforced idleness that will occasionally come to him, he should methodically add to his professional knowledge and by writing and speaking advance the widespread understanding of the activities and ideals of his profession. He should seek the company of the highest types of men in his field and the benefits to be derived from contact with brilliant minds. He will cultivate habits of industry and saving so that his capacities for useful service will not be curtailed or prevented by improvidence.

THE FUTURE OF THE PROFESSION

Opportunities for success in mining and metallurgical engineering are probably greater than those in any other profession. Since the day when the first savage pounded a lump of copper into the semblance of a spearhead, civilization has advanced no further than the limits prescribed by the mining and metallurgical art of the time. Lacking an enormous annual tonnage of metals, civilization as known to modern man would cease to exist. This supply must be produced from ores of decreasing grade, mined under more and more costly conditions; and the men who can apply their science and inventiveness to this task with high efficiency, executive skill, and a minimum of injury to workers, and without encouraging the human tendency to gamble in fictitious values, will discover that the world is not slow in rewarding their efforts. Contemplation of the careers of such venerated men as Sir Henry Bessemer, James Douglas, C. LeNeve Foster, Herbert Hoover, James Furman Kemp, Raphael Pumpelly, Rossiter W. Raymond, Robert H. Richards, W. C. Roberts-Austen, and Sir Thomas Rose cannot but bring to the generations of their successors some true comprehension of the high ideals to which their lives should be consecrated.

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